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Exploring Passive Solar Design in Minnesota's Residential Construction Sector

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Abstract

This directed project analyzes the cost and benefit relationship of incorporating passive solar heating and cooling designs into a national home builder's standard house plan. The orientation, glazing area, glazing type, and solar shading features of the home are all analyzed. The goal of this directed project is to determine if passive solar can make an impact on energy costs for a national home builder's standard house plan. The focus of the study is on one standard home plan and analyzing what impact passive solar design changes can have on annual heating and cooling energy consumption. The construction costs of the design changes are calculated along with the payback period. These changes are designed to be easily reproducible and able to be applied to other homes in the regional market. The results are a very straight forward analysis that shows builders, developers, and homeowners what effects passive solar can have on standard home plans. The ultimate goal is to overcome the current barriers that have prevented widespread adoption of passive solar and bring it to the forefront of design in the mainstream residential construction market. The study utilized the residential energy simulation program called RESFEN 5.0. RESFEN 5.0 was used to calculate the annual heating and cooling loads for the simulated test home. The program allowed for variations in glazing areas, orientation, window types, shading effects, and most importantly energy costs. The conclusions of the study will show if there are certain design strategies could help to reduce the residential energy consumption for a standard national builder's home in Minneapolis, Minnesota.

Statement of Problem

The mainstream residential construction market in Minnesota has not adopted passive solar as a legitimate solution to reduce heating and cooling demands. Currently heating and cooling costs are the largest annual energy expense for homeowners living in Minnesota.

Significance of the Problem

The majority of the energy produced currently in Minnesota is from burning fossil fuels. Fossil fuels are a limited resource and the cost of these resources has steadily increased for the past 50 years. Even though new homes have become more efficient in the last decade, the overall size of the average home has increased. Population levels also have continued to increase in Minnesota along with the number of homes being constructed. The number of occupants in the average home has decreased over the last decade resulting in more homes being built for smaller households.

The increase in heating and cooling costs will continue to be a significant portion of the average homeowner's budget unless something can be done to reduce energy consumption. The current energy efficient improvements in Minnesota's residential construction market have been offset by larger homes and fewer occupants. The overall energy consumption continues to increase along with the heating and cooling energy unit prices.

Statement of the Purpose

The purpose of this directed project is to provide the cost versus benefits analysis of passive solar design strategies on a standard residential home in Minneapolis, Minnesota. The goal is to analyze minimal passive solar design changes that could be widely adopted across the housing sector in the Upper Midwest region of the United States.

Objectives

The main objective of this directed project is to analyze the potential energy savings that can be achieved from designing residential structures to respond to their local climate by utilizing passive solar heating and cooling strategies. This project develops an accurate estimate of the additional costs associated with implementing these passive solar heating and cooling design strategies. The study then compares the additional costs of the passive solar heating and cooling design strategies to the potential energy savings. The result from this study is an easy to read comparison for how minimal changes in a home's design could potentially affect energy savings. The ultimate goal would be for builders, developers, and homeowners to see the impact that passive solar heating and cooling can have on energy usage. This information could then be used to increase the amount of new residential homes that utilize passive solar heating and cooling design strategies. If passive solar can start to be utilized as a standard building practice then significant amounts of heating and cooling energy can be conserved each year.

Definitions of Terms

Passive Solar – Is building design that uses the sun's energy along with the local climate to maintain a thermally comfortable living space. In most cases passive solar design leads to net energy reduction used for mechanical heating and cooling. (Morrissey, Moore & Horne, 2010)

Direct Gain- Refers to a passive solar collection system that relies on sunlight passing through glass to heat an interior space. Most direct gain systems consist of an insulated building with a relatively large expanse of glass which admits rays of the sun. Direct gain systems collect solar heat and reduce heating loads in cold climates. (National Fenestration Rating Council, 2011)

U-Factor- Measures how well window glass prevents thermal transfer from the inside of a space to the outside. Most U-Factor ratings typically range between 0.20 and 1.20. The lower the U-Factor the better the glass is at preventing thermal transfer. U-Factor is particularly important in cold climates during the winter months. (National Fenestration Rating Council, 2011)

R-Value - Is the measure of resistance to the flow of heat through a given thickness of a material (as insulation) with higher numbers indicating better insulating properties. R-Values typically measure the resistance of walls, ceilings, or other solid materials. (National Fenestration Rating Council, 2011)

Solar Heat Gain Coefficient (SHGC) - Measures how well a product blocks heat from the sun. SHGC is expressed as a number between 0 and 1. The lower the SHGC number the better a product is at blocking heat gain. Blocking solar heat gain is particularly important during the summer cooling season. (National Fenestration Rating Council, 2011)

Shading Coefficient (SC) - The shading coefficient is a measure of the total amount of heat passing through the total glazing (known as the total solar heat transmittance) compared with that through a single clear glass. The shading coefficient (SC) is derived by comparing the solar radiant heat transmission properties of any glass with a clear float glass having a total solar heat transmittance of 0.87. (National Fenestration Rating Council, 2011)

Visible Transmittance (VT) – The visible transmittance value measures how much light comes through a piece of glass. VT is expressed as a number between 0 and 1. The higher the VT value the more light is passing through that object. (National Fenestration Rating Council, 2011)

Assumptions

Standard home designs need to be completely rethought to take full advantage of a passive solar heating and cooling benefits. The amount of energy reduction that could be achieved by redesigning the standard American home plan could greatly reduce the energy demands across the country. Additional advancements in HVAC and insulating technologies can then be applied to achieve the maximum results. This complete change in overall design will allow homes to maximize their energy conservation potential.

The energy modeling of this study is fairly straight forward but the cost implications will be much harder to determine. There are high variables on the cost of products going into new homes that are currently being built. These cost fluctuations could potentially make any energy savings negligible when it is compared to the cost implications of design changes.

This study quantifies some of the more common passive solar heating and cooling design strategies. These design changes are not revolutionary but they are relying on new energy modeling software to simulate how effective they can be.

Most homeowners do not realize the potential energy savings that can be achieved by utilizing passive solar heating and cooling design strategies. This study will help explain what passive solar design strategies are and which ones are the most cost effective over the life of a home. By producing the basic cost and benefit information this directed project increases the awareness of home buyers, developers, and builders. Depending on the significance of the information it could potentially start to change the acceptance of passive solar as a feasible way to reduce heating and cooling energy consumption.

To achieve this energy savings in a cost efficient manner the standard home design needs to change. There are design changes that need to be made to the house that most people do not think of when they are looking at their new home. The majority of the windows will need to be orientated on the south side of the house to take advantage of the low winter sun. There will also need to be small changes to the outside of the home to help block the summer sun from overheating the home.

The majority of homeowners and builders this study is designed for are only willing to pay a reasonable amount of additional money upfront for the passive solar heating and cooling strategies. The goal of this study is to get homeowners to look at the long term monetary gains by living in an efficient home and see the true benefit of conserving energy. It is very hard to determine how much additional money home buyers are willing to spend on the construction of a passive solar home. Homeowner's willingness to pay more money for an energy efficient home might change when they are analyzing all the optional features and finishes for their new home. The passive solar design strategies might be eliminated from the budget when other design options are considered.

Delimitations

There are numerous passive solar heating and cooling technologies that are being practiced throughout the country. This study is focused on direct gain passive solar heating and solar shading passive cooling technologies for the Upper Midwest portion of the United States, more specifically Minneapolis, Minnesota. The efficiency of the strategies will be measured by the amount of energy that is conserved by the implementation of the passive heating and cooling technologies. By only focusing on these two passive energy design strategies the cost implications and energy consumption variations will be more accurate. This study will allow for a very straight forward analysis of the benefits and the cost of the design changes.

Passive heating and cooling relies on precise orientation and design of structures to maximize the energy savings benefits. The goal of study is to implement passive heating and cooling strategies on standard production homes in standard residential developments. One of the delimitations will be that current residential developments do not take home orientation into consideration when the lots are laid out. The current practice is to maximize the lots on a plot of land to get the highest return on the investment. This study assumes that the perfect placement of the glazing area is achievable which will be very difficult to find in current residential developments.

Homeowner behavior will also be very hard to control. The passive solar heating and cooling strategies rely on homeowner interaction for the maximum energy savings. The study is going to assume the best case scenario where the homeowner is doing their part to control the passive solar systems. It will be difficult to predict homeowner behavior and how regularly they will interact with the passive system to maximize the energy savings.

If complex passive solar heating and cooling design strategies are studied at the same time, the effectiveness of each will be hard to calculate on the test home. If simple design changes are analyzed individually then the impact of the change will be obvious in simulated energy consumption. Then variation in energy usage can be analyzed to determine if the construction cost was worth the difference in overall energy consumption.

Limitations

The main limitation of this directed project is that it is going to be a simulated case study. Even thought this might be seen as a limitation the current energy modeling software allows for small changes to be analyzed over time. All of the energy modeling will be very accurately simulated but it is sometimes hard to get the real life results without building the actual house. In an actual home the occupants will generate different amounts of heat depending on their activities. Heat from cooking and interior light fixtures could produce variations in the total amount of required heating and cooling loads.

The study will also be limited by location. The study will be based in the Upper Midwest and the results will be only relevant for similar climates. The study only analyzes design changes on a single home plan and might not be applicable to all home plans.

Some of key concepts that help standard passive solar homes be successful will have to be ignored to simplify the testing data. The thermal mass of a passive home is generally very important for the home to store the energy and balance the house. The software program that is being utilized to simulate the data does not have any options for thermal mass. Passive solar homes rely on some very high levels of insulation so they are able to store energy that they capture from the environment. Increases the insulation levels would mean moving away from a traditional 2x6 framed exterior wall. This would be a drastic change for current residential construction. The thermal mass and insulation levels will remain at the current levels so other variables can be examined. With these two key aspects of passive homes being ignored the assumption will be that there is still going to be data variations in energy consumption but it might not be as drastic of ranges.

The impact of the design changes will be hard to explain to people without actually being in the space and seeing the outside of the test home. It is an assumption that most homeowners would be receptive to saving money with the passive solar design changes but when it comes down to it might not be what they would do in real life. This directed project is as accurate as it can be but the fact that the study is based on simulated data it might be seen as a weakness.

Literature Review

Introduction

The human race has been utilizing the unique climatic features in their environment to improve the comfort of their living conditions since the first shelters were created. The heat of the sun, the cooling effect of shade, and the evaporative effects of a breeze are all natural characteristics that improve human comfort. Primitive cultures designed their shelter to take full advantage of the surrounding environment. These primitive structures responded to the local climate in which they were built and increased the comfort level of their inhabitants. These unique climatic conditions can be harnessed to help improve human comfort while reducing heating and cooling energy consumption.

Energy Conservation

The current trend in the residential construction industry is moving toward an emphasis on conservation. The building industry currently appears to be entering an era where the focus is placed on minimizing the energy footprint of both commercial and residential buildings. (U.S. Department of Energy, 2007) A main part of energy conservation building practices has been an attempt to become more efficient with the resources that a home consumes. This includes both the material that goes into producing a home but also the energy that a home consumes on an annual basis. The overall goal is to reduce the amount of energy and resources used to heat and cool structures.

The recent improvements in the residential sector are focused on two main areas of the home design. One of those areas focuses on the exterior insulation of the structures. The improvements have primarily been around improving insulation and building envelope performance. The other main area of improvement has been centered on utilizing more efficient heating, cooling, and air conditioning (HVAC) equipment. Energy efficiency improvements have been achieved in heating, ventilating, and air conditioning, in addition to improvements in windows and insulation. The result of these changes produced a nine percent decrease in energy consumption per household between 1985 to 2004. The increase in energy efficiencies was not enough to offset the increase in the number of households and the average house size. The overall total amount of energy consumed across the residential housing sector increase from 1985 to 2004 despite these improvements in the building industry. (U.S. Department of Energy, 2009)

The United States Government has been encouraging energy reduction in the residential sector. The U.S. Government has been offering tax credits to update window, furnaces, air conditioning units, and insulation. The government has also stepped in and has started to influence local building codes.

State energy codes have continued to require more efficient homes that have improved levels of insulation and HVAC systems. This has been a factor in moving the residential industry as a whole to a higher energy efficient standard. More and more new homes are being constructed to meet new these new energy efficient standards and the trend seems to be catching on with home buyers. In a recent study, 46 percent of new home buyers listed energy efficiency as a one of their primary considerations in purchasing their new homes. (U.S. Department of Energy, 2009)

There is now a minimum level of insulation that can be used on the walls, attics, and floors of homes. The windows that get installed in new homes need to meet certain U-factors and SHGCs for different areas of the country. These building codes even mandate a certain level of energy efficient furnaces and air conditioning units.

Current Energy Usage

The United States is currently the number one largest energy consuming country in the world. In 2006, the residential sector accounted for 20% of the total energy used in the U.S. Space heating and air conditioning accounted for 44% of all energy used in the U.S. residential sector. Slightly less than 10% percent of all the energy used annually in the U.S. is devoted solely to heating and cooling our homes (U.S. Department of Energy, 2009). Figure 1.1 illustrates that space heating and cooling make up a significant amount of the average homeowner’s total energy usage and monthly energy bill. Reducing the energy used to heat and cool homes could have a drastic benefit for the consumer and the environment.

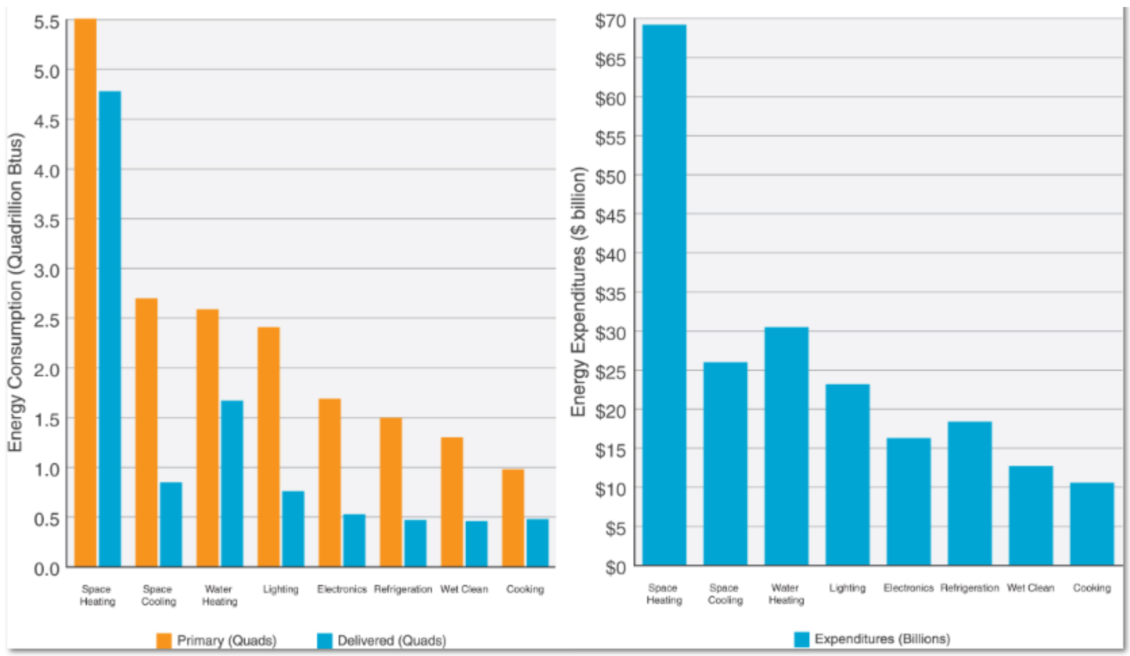


Figure 1.1: Primary & delivered energy and expenditures for Energy, by end-use. (U.S. Department of Energy, 2009)

In 2009 the residential sector in the U.S. consumed approximately 20% of all the energy used across the nation. The residential sector uses approximately 35% of all the electricity produced in the U.S. and is strongly dependent on natural gas for heating. (Parker, 2008) Supplying energy to the residential sector in the U.S. generates fully 18% of its greenhouse gas emissions. Despite technological improvements in refrigerator, furnace efficiency, and energy codes improving insulation, many American lifestyle changes have put higher demands on heating and cooling resources.

The average home size in the U.S. has been steady increasing for the last 30 years. In 1970 the average home was approximately 1500 square feet. In 2005 the average home size increased to approximately 2300 square feet. The average amount of occupants per home has decreased and two-person household have become much more common. The amount of energy used for cooling has also increased due to more households have central air conditioning. In 1978 only 23% of U.S. households had air conditioning. In 2001 approximately 55% of U.S. households had air conditioning. Since 2000 the electrical use in U.S. households has been dramatically increasing due to the increased use of electrical devices in daily activities. All of these changes have led to an increase in energy consumption which has largely offset the efficiency gains in residential structures. (Parker, 2008) Even though the United States is becoming more energy efficient the overall amount of energy consumed is not being reduced due to larger homes and current lifestyle trends.

Current energy generation takes continual inputs of money and resources to produce. The world's current methods for producing energy require resources that do not have infinitive supplies and create byproducts that have negative effects on our environment. New green energy mandates and proposed laws could drastically increase the cost of energy in the next decades. Any viable solution that could reduce the amount of energy consumed would appeal to both home buyers and the governmental energy policy makers. Home buyers and government mandates could then start the demand for these energy savings design techniques to be included as standard features on new homes.

Project Climate

The testing simulations are based on a home plan in the climatic zone of the Upper Midwest region of the United States. The climate of Minnesota has cold winters and hot summers. Minnesota's location in the Upper Midwest allows residents to experience some of the widest variety of weather in the United States. Each of the seasons in Minnesota has its' own distinct characteristics. (U.S. Department of Energy, 2007) Midwest homes require a large amount a heating in the winter and an average amount of cooling in the summers. Passive heating technologies will be the main focus of this directed project but it will also have some cooling technologies as well.

This directed project analyzed basic design strategies that focused on utilizing passive solar to reduce energy consumption on a home in Minneapolis, Minnesota. Minnesota is the in the Upper Midwest region of the United States. Figure 2.1 shows that the Upper Midwestern region of the United States falls into the "cold climate" which was determined by the U.S. Department of Energy Building America Program. Cold climates are generally defined as a region with approximately 5,400 heating degree days or more and fewer than approximately 9,000 heating degree days. The degree-day measurement is the difference in temperature between the average outdoor temperature over a 24 hour period and the average temperature for a living space, typically 65°F. (U.S. Department of Energy, 2007)

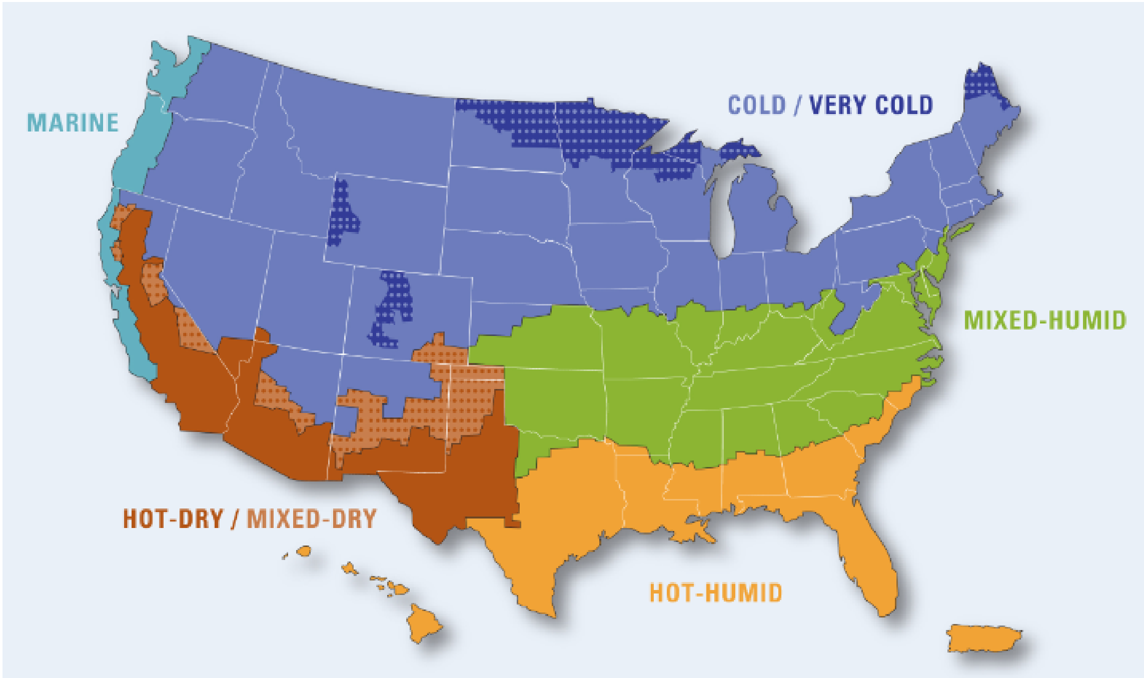


Figure 2.1 Climate Regions. (U.S. Department of Energy, 2009)

This study is primarily focused on passive solar heating but also analyzes passive cooling strategies. Minnesota has a wide variety of hot and cold temperature swings. It is critical that the test home perform well in all environmental conditions that it are typical to the in Upper Midwest climate.

Urban Planning

Currently developers and planners do not take into consideration unique climatic features when residential lots are laid out. Since the currently emphasis is focused on the density of the developments there is a lack of experience and expertise for planning environmentally sensitive projects. The consideration for the orientation of the homes in the development is not a factor when the layout of lots is configured. (Scott, Edge & Laing, 2006) By presenting developers and planners with more knowledge on the basics of passive solar then projects might start to be focused around taking advantage of the benefits of the natural environment. If passive solar can be achieved in standard residential construction and the potential energy savings are quantified then some change might start to be considered when planning a new subdivisions.

One of the major problems in encouraging more environmentally friendly mass house projects is the initial approach taken by developers. When the initial decisions are made on a development a lot of choices are made to optimize the sales values which typically do not favor environmentally friendly designs. The footprint of the development is decided early on and there is little chance of changing the footprint as it moves forward through the construction process. (Scott, Edge & Laing, 2006) At some point since the invention of air conditioning and the evolution of the current modern urban planning methodology these basic passive solar design strategies have been abandoned in main stream residential construction.

Passive Solar

Passive solar is using the sun's energy to help maintain thermal comfort in living spaces. Passive solar can provide reduction in both heating and cooling energy demands on a building. Building materials have to be chosen vary carefully to optimize the sun's energy throughout daily and seasonal changes. The design of buildings also need to be critically analyzed to determine how passive solar can be utilized to the fullest extent in the given structure and climate. In most climates a passive solar design will typically provide a net reduction in energy used to heat and cool the living space. (Morrissey, Moore & Horne, 2010).

Passive heating is based solely on utilizing the solar gain from the sun. There are numerous ways to achieve the solar gains but the main principle remains the same. There are two main ways to store the solar radiation of the sun. By placing glazing areas toward the equator, the sun's rays can be allowed to penetrate into a structure and heating the interior of the space, similar to a greenhouse. Too much sun could cause the negative effect of overheating a space during the summer or daytime hours. The other main passive solar heating method utilizes the mass of the structure. The heat from the sun’s rays are stored the mass of the structure and slowing radiated throughout the night time hours. This method counteracts the cooler night temperatures and the helps eliminate the need for night time heating.

The direct gain heat from sunlight is the simplest way of achieving passive heating. In this system, sunlight enters through windows or skylights (glazing) and is absorbed by the inside surfaces of the building. In a direct gain system, thermal collection, dissipation, storage, and transfer of energy take place in the living space of a home. Direct gain is the most effective form of passive solar heating both in simplicity and total energy production. The direct gain method also offers the added benefit of allowing natural daylight to enter in the living space. The direct gain system is also fairly easy for the occupants to control with the use of curtains or blinds to block the sunlight. (Morrissey, Moore & Horne, 2010).

The main goal when determining the correct amount of glazing is to calculate the amount of mass that needs to be heated. It is important not to overheat the structure during the day and provide enough insulation to store the heat during the night hours. There are two main ways that heat is stored in homes. There is heat that is stored from the sun in the mass of the building. This heat is giving off at night and the temperatures of the thermal mass and inside air try to equal each other. In winter the goal is to achieve high solar gain during the day and store the heat energy in the thermal mass of the building. The absorption into the thermal mass helps reduce overheating in the living space. When the temperature drops during the night the heat energy from the thermal mass is released which helps to keep the living space warm and reduces mechanical heating costs. (Kalogirou, 2009)

Passive solar is relatively inexpensive when it is incorporated at the design stage of a home. It simply requires placing windows to maximize winter solar heat gain and minimize summer heat gain. It also involves choosing materials that have thermal mass to store heat energy or increasing the home's insulation rating. In China, more than 200,000 tons of coal is saved annually because most buildings face south to take advantage of solar heat gain. Despite considerable potential, there are still very few passive solar homes being built in the U.S. (Garrett & Koontz, 2008)

The other way heat is stored is the prevention of the solar gain from escaping the home through a well-insulated exterior shell. Since this study is focused on changes that can be implemented across the housing sector the thermal mass of the structure will be ignored. Increasing the thermal mass of a home has numerous thermal performance variations and limits homeowner's options for selecting interior finishes. Increasing the thermal mass also relies on the specific interior design of the home which for the most part is an aspect that will be ignored during this study. This study will rely on the high performance of the exterior insulation of the standard new home. This study will keep the current home plan's thermal mass and the insulation levels so the results can be compared to a broad spectrum of new house designs. The main principle of passive solar in cold months is storing the heat during the winter days and trying to use it to supplement night heating.

Insulation and thermal mass work the same way in summer. By utilizing night venting techniques the thermal mass of a structure can cooled down at night. The cool mass and insulation then neutralizes heat gain during the day. Natural ventilation works with the thermal mass of a building and absorbs cold night temperatures. The thermal mass of the building then cools the conditioned space of a building during the day and reduces the need for mechanical cooling. The combination of thermal mass with natural ventilation can be used to lower energy consumption and increase the sustainability of buildings. (Zhou, Zhang, Lin & Li, 2008) Night cooling and natural ventilation are an added benefit but very hard to quantify the benefits. Homeowners will have to keep in mind that added windows will increase the venting performance of their homes but quantifiable results are extremely difficult to calculate. The exact location of a home and its' surroundings play a key role in determining how effective cross ventilation can be in helping to cool a home. Surrounding trees, home orientation, and window location can all play a critical role in determining how affective natural ventilation will be.

The orientation of the building and windows is generally regarded as an important aspect when designing a passive solar structure. In colder climates where heating is required the sun can be utilized for direct solar gain. If the structure and the majority of the window face south then the sun can reduce the mechanical heating demands. If the structure or windows were ordinated to the east or west the benefit of the solar heating gain would be reduced. (Morrissey, Moore & Horne, 2010)

The Upper Midwest region of the United States has very cold winters and mild to hot summers. The key in designing a passive building is to orientating the building so the longer sides of the structure are facing north and south. This allows for maximum solar penetration during the day and results in the maximum amount of heat gain. The optimal orientation of the windows should be within 30 degrees of true south. During winter months the windows should not be shaded from 9 a.m. to 3 p.m. to maximize the solar heat gain. The windows in living areas should face south because they are larger will not overheat as easily. The windows in bedrooms should face north so because they are smaller which are more likely to overheat and they are not typically occupied during the daytime hours. (U.S. Department of Energy, 2009) The key to this design is to incorporate shading devices so that the higher angled sun in the summer months is blocked and the lower angled sun in the winter months is allowed to penetrate into the structure.

Solar shading can be any device of obstruction that blocks the sunlight. Solar shading devices can be on the interior of a home or on the exterior. The most effective way to block the solar heat gain is on the exterior of a structure. Solar shading devices are important components in highly glazed buildings. They allow homeowners to avoid glare and provide options for the occupants to reduce solar gains through windows in the summer. Certain shading devices also offer the flexibility to be retracted in the winter to maximize solar heat gain. (Loutzenhiser, Manz, Felsmann, Strachan & Maxwell, 2006)

Exterior shading options can be roof overhangs, awnings, solar shades, window tint, or solar screens. Anything that can block some or all of the sun's rays before they hit the window surface is an effective solar shade. Interior blinds, curtains, and window coverings are effective at reflecting some solar heat gain but there is some heat that gets dissipated to the interior space of the structure.

The amount and type of glazing in a passive solar home is critical to the overall performance. In a cold climate the majority of the glass should face south. There are two main characteristics that should be reviewed when selecting windows.

The amount of insulation that a window has is measured as a U-Factor. The lower the U-Factor is the higher the window's insulation level. The other factor that is critical to passive solar windows is the solar heat gain coefficient (SHGC). The higher the SHGC the more of the sun rays are allowed to penetrate through the window and heat the interior of a home. The impact of a window's U-Factor and SHGC will be examined in depth during the simulation phase of this project.

Worldwide Passive Solar Design

Germany has been at the forefront of passive heating and cooling designs for residential structures. This trend was initiated by the government and it seems to be picking up momentum. In 2000, the German government decided to cut greenhouse gas emissions by 25% by 2005. (Badescu & Sicre, 2003) As a result the construction industry was pushed to start building "Passive Houses". Passive houses are buildings that assure a comfortable indoor climate during summer and winter without needing any conventional heating or cooling system. The standard has been named "passive house" because the passive heat input-delivered externally by solar irradiation through the windows and provided internally by the heat emission of appliances and occupants is essentially enough to keep the building at comfortable indoor temperature throughout the heating period. (Badescu & Sicre, 2003)

The German Passive house trend is starting to build momentum in the U. S. There is currently a Passive House Institute that has been established in the U.S. The institute assists with training architects and builders on how design and build passive homes. The biggest contribution that the passive house technology is having on the residential building sector is directing focus on the exterior walls of homes. Passive homes produce results that show by having a virtually air tight and super insulated exterior they can dramatically reduce heating and cooling costs. This evidence is pushing the evolution of the home design back towards super insulated exterior design along with utilizing passive solar for modest heat gain.

Poland also has a significant amount of research and practice with passive solar technology. Poland's climate demands very strict building orientation and thermal massing to make passive solar successful. To maximize the passive solar heat it is recommended that the building be orientation so the largest façade be within 10 degrees from south to south east. It is also recommended to design living areas and other buffer zones on the south side of the building. The homes in Poland also have to be equipped with shading devices like overhangs or wing walls. When there are areas of large amounts of glazing areas the home must be equipped with curtains or other window coverings to reduce heat losing winter. It is estimated that passive solar could save 30% of the energy Poland currently expends on space heating. (Chwieduk & Bogdanska, 2004)

In Australia passive solar designs are starting to become popular. The Australian government is trying to start a program to encourage homeowners to build passive solar homes. Building officials actually have changed the building code to try to force some areas to build energy efficient homes. The building officials feel it is an important topic and that homeowner will benefit from the technology. The houses that are being built in Australia today will most likely remain for the next 30 to 70 years. For that reason it is important for passive solar principles be designed into these home to help reduce their energy consumption. Passive solar design is recommended as a path beyond minimum building standards to deliver better energy efficiency. Australia is currently trying to make a deliberate and positive impact on improving the livability and energy efficiency of future housing stock through sensible passive solar design. (Peterkin, 2009)

Current Residential Market

The main resource that is being ignored in the residential housing market is the natural energy produced by the sun. This energy is free and abundant but it needs to be harnessed from the natural surroundings. Simple passive solar design strategies can be incorporated into homes that could greatly reduce the need for heating and cooling. These design strategies are not new technology and have been practiced by cultures throughout history. The main strategies involve harnessing the heat that is produced by the sun, blocking the sun through solar shading, and orientating the home to take advantage to access the sun.

The first step to achieving the benefits of passive solar is to redesign the structure of a home so it can fully take advantage of the climatic conditions of a unique location. Before the invention of HVAC (heating, ventilating, and air conditioning) structures were designed to take advantage of the local environmental conditions. Once the buildings could be mechanically heated and cooled the design of homes began to focus of aesthetics and ignored the benefits of the surrounding climate.

Passive solar strategies are design features on homes that do not use mechanical means for heating, cooling, or ventilation. Instead either some or all of the conditioning relies on the design features that use the sun and the local climate to condition the living spaces. Current passive solar strategies take advantage of these natural climatic conditions by harnessing the power of the environment which in turn helps the reduce energy consumption.

Even though most conventional homeowners are not familiar with passive solar design they are predisposed to favor it. This is true, especially if it can be incorporated into traditional housing styles. (Garrett & Koontz, 2008) The problem is that even though passive homes have been around for a number of years the trend has not caught on with the main stream residential construction industry.

The majority of successful passive homes have unique designs that respond to their climate and make them highly effective in utilizing the environment. Passive homes are traditionally slightly more costly to build and much tighter tolerances on design details that enhance the home performance. Not every homeowner is familiar with passive solar design which reduces the demand to build homes that meet those criteria. Not every home builder is knowledgeable enough to build a passive solar home which in turn reduces their availability. Both of these factors reduce the adoption rate of passive solar homes. (Garrett & Koontz, 2008) All of the factors above have led to a very slow adoption of passive heating and cooling strategies in the residential construction market.

Even if potential home buyers like the existing design of passive solar homes the availability of those types of home pose a problem. Several characteristics of the typical residential construction industry impede the adoption of innovation. The small scale of most residential construction companies hinders change and causes adoption of new technology to be minimal. The ups and downs in the housing market also create unwillingness on the part of builders to take big investment risks. Some housing innovations are often hidden in construction process and are therefore unobservable to most homeowners. The varying regulations of different cities and counties are also barriers to widespread innovation. The focus that builders and homeowners have on upfront costs rather than the performance of homes prevents many potentially useful advances in residential building technology. All of these factors reduce the availability of passive solar homes and keep the residential construction industry in the current status quo. (Garrett & Koontz, 2008)

There is already some research as the user experiences in passive solar homes. There were some detailed surveys performed on a community of passive solar home residents in the United Kingdom. The overall results from the survey seem to indicate that the majority of homeowners that choose to buy passive solar homes make their decision because they are looking for a low cost, comfortable way to heat their homes. The majority of the homeowners in the study also agree that they were satisfied with the aesthetics and the energy performance of their passive solar homes. (Yakubu, 2006) This information provides some key insight as to what attributes would stimulate homeowners in the U.S. to purchase passive homes. The key attributes of the United Kingdom homeowners seem very similar to current home buyers in Midwest home market. The main points from the survey are that the user experience is positive and the users see a value in owning a passive solar home. This data seems to support the theory that if an adequate supply of passive solar homes can be produced for a reasonable price trade off then homeowner might consider that type of design.

From September 2009 to September 2010 the U.S. Department of Housing and Urban Development estimated that there were 321,000 new homes sold in the U.S. The top one hundred home builders in the nation sold 153,702 homes (U.S. Department of Housing and Urban Development, 2011) Those figures roughly calculate to approximately 48 percent of all the homes that are sold in the United States each year are built by the top 100 builders. National home builders lead the residential markets and they are on the cutting edge of building trends. The volume and repetition of national home builders could allow passive solar heating and cooling technologies to move from the fringe to mainstream in the residential construction market.

Literature Review Summary

The U.S. is currently one of the world leaders in energy consumption per person. There is a substantial amount of energy used to heat and cool residential structures across the country. The current mainstream energy reduction strategies do not take into consideration any energy reduction passive soar could provide. Passive solar is a proven technology that can be utilized in multiple climates to achieve reduced heating and cooling energy usage. Even though passive solar is a proven technology it has not been adopted as a common building practice by the architects, builders, developers, and homeowners.

The market share and construction volume that national home builders have could potentially start widespread adoption of passive solar in current residential construction. If modest passive solar technology can be successful implemented on a national builder's standard home plan then it could start to be offered as an option to homeowners. This directed project addresses those questions and provides a cost benefit analysis of passive solar being implemented on standard residential homes.

Simulation Procedures

A standard home plan was selected from one of the top fifty national home builders that are currently operating in the Minneapolis area. The house plan was analyzed and the all of the information was uploaded into RESFEN 5.0. The key data was the total square foot area of the home, the window area on each façade of the home, the current insulation levels, and the window performance characteristics.

The standard home plan was a very common design that is built in the Minneapolis area. It is a two story wood framed home with a full basement. The overall square footage of living space was 2,225. The glazing on the house plan was 125 SF for the front, 0 SF on one side, 20 SF on the other side, and 200 SF on the back side of the home. The walls are 2x6 construction and the insulation levels are right at the standard that Minnesota's building code requires. The attic has an insulation level of R-38, walls are R19, basement slab is R10, and rim joist areas are R10. The wall thickness is going to remain constant for the simulations so it would eliminate a lot the cost variables with framing and additional cost with trimming out the wall openings. See Figure 3.1 and Figure 3.2 for a graphic representation of the model home that was used as the base for the testing.

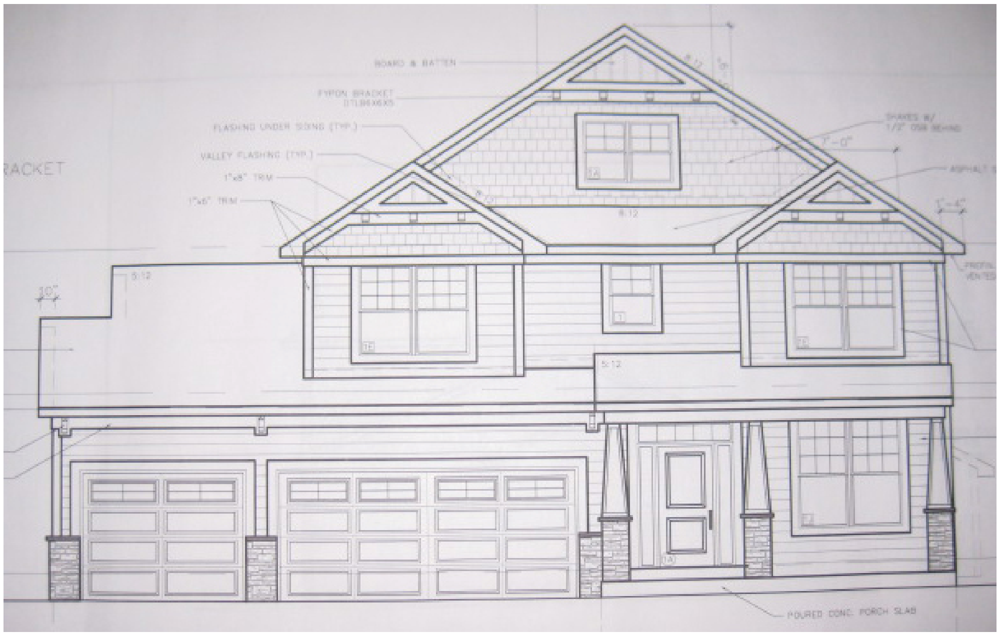


Figure 3.1. Front Elevation of Standard Home Plan

Figure 3.2. Back and Side Elevation of Test Home

RESFEN 5.0 was chosen for these simulations because it is currently the only residential energy modeling software that allows for users to make significant changes to the glazing material and area on a simulated home. RESEFEN 5.0 allows for wall insulation levels to be selected. The furnace and air conditioning types can be selected along with their efficiency levels. RESFEN 5.0 also allow for different types of window coverings to be selected to either reduce or increase solar gain. All of these options made

RESFEN 5.0 the most logical selection for the energy modeling program used in this study.

Since no other energy modeling program could not be found to validate the results that were produced from RESFEN 5.0 it was necessary to validate the program in other ways. Several research papers were found that helped to explain how RESFEN 5.0 calculated the energy consumption and also validated the program through test homes that were entered into the program.

RESFEN 5.0 uses a customized version of DOE-2.1E that computes all the variables of the energy simulations. DOE-2 is a dynamic hourly building energy simulation program that is well known to engineers and energy researchers in the U.S. DOE-2 has been modified so that it can be used in the RESFEN program but the algorithms have not been altered so it will give identical results. (Huang, Mitchell, Arateh & Selkowitz, 1999) DOE-2 was not selected for this study because it requires significant user experience to use the program effectively. RESFEN 5.0 on the other hand is very user friendly and most homeowner could handle doing energy modeling with its' simplified user interface.

DOE-2 has been validated by energy modeling on real life test homes. In California there was study where DOE-2 energy modeling was performed on eight test homes. The internal temperature of these homes were physically recorded and then compared to the simulation results of the DOE-2 program. The results showed that the DOE-2 is in excellent agreement with the measurements of all eight housing configurations. The cases that were considered were representative of real world houses that would be encountered across the U.S. (Meldem & Winkelmann, 1995)

RESFEN 5.0 has stored data for energy costs or users can manually input data for the local energy costs. The stored energy data for Minnesota that was in the software was out of date and not accurate with current costs. Using several bills from different energy suppliers the current Therm price was estimated to be $0.853 per Therm. The same procedure was used to estimate the kWh for the electricity consumption. The electricity rate was estimated to be $0.10 per kWh. The test home had a natural gas furnace and electric air conditioner. By having two different heating and cooling systems it allow the heating and cooling costs to easily be separated. See Figure 4.1 for an example of the RESFEN 5.0 program and the options for inputting different home characteristics.

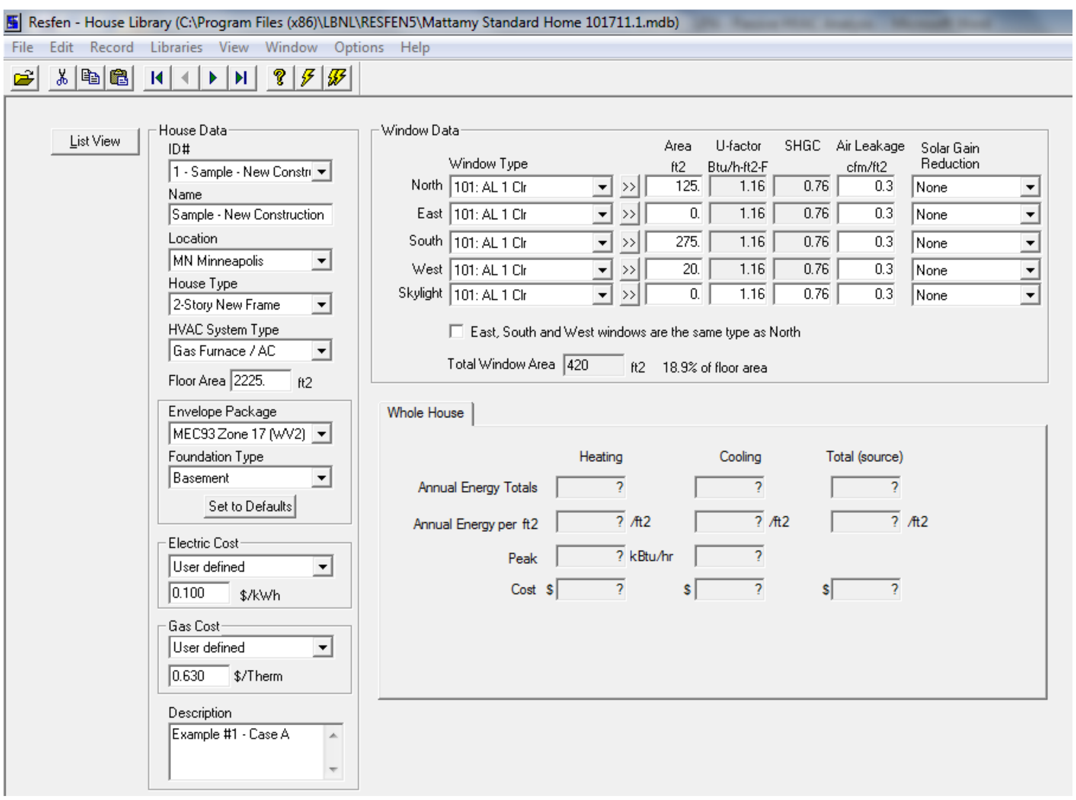


Figure 4.1. RESFEN 5.0 Energy Modeling Software

The next step was developing two alternative home plans that would be used to test the proposed changes to the annual energy consumption. Hybrid House Plan A was the simulated house plan that would be used to test an increase in the glazing area. Hybrid House Plan A had 267 SF (square feet) of glazing on the back side of the house in comparison to the standard house plan that had 200 sf. The quantity of 267 SF of glazing area was selected because the glazing area on any single side of the home cannot exceed 12% of the total square feet of the home. This is a restriction that RESFEN 5.0 has built into the programming constraints and it cannot be altered. This 12% window to wall ratio is mandated by the International Energy Conservation Code (IECC) which takes into consideration the insulation levels and home location. Hybrid House Plan B was developed to test a reduction in the glazing area on the back side of the home. Hybrid House Plan B had 125 SF of glazing on the back side of the house.

The front and sides of all the house plans were kept at the same glazing percentages so the only variable on glazing amounts would be the back side of the home. This test design would allow the simulated data to show how the glazing percentages would affect the energy used on heating and cooling the structure. The orientation direction refers to the directions that the front of the home would face.

RESFEN 5.0 has 36 standard windows that can be used in the energy simulations. Unfortunately no manual U-factors or SHGC factors can be added to create custom windows. The 36 standard windows in the library had a wide variety of U-Factors and SHGC values. Nine windows were selected for the simulations. The chart below show the nine windows were selected to give a range of U-Factors in addition to a range of SHGC values.

Window Type	U-Factor	SHGC
101: AL Clr	1.16	0.76
311: w/v 2 Clear	0.49	0.56
351: W/V 3 HT Super	0.28	0.38
352: W/V 3 SS Super	0.28	0.25
411: Ins 2 Clear	0.44	0.6
421: Ins 2 PY Low E	0.29	0.56
431: Ins 2 SP Low-E	0.27	0.46
441: Ins 2 SS Low-E	0.26	0.31
451: Ins 3 HT Super	0.18	0.4

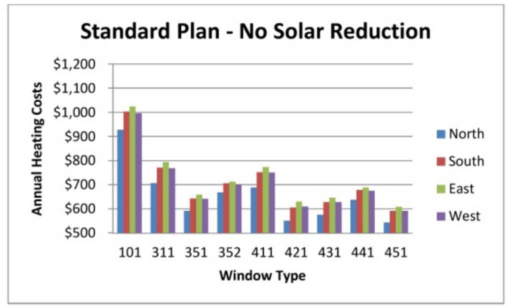
Table 1.1 RESFEN 5.0 windows used in simulations

The first part of the simulation testing was focused on determining the amount of energy that is consumed heating the test homes in the winter months. The orientation of the home, the glazing area, and the glazing types were all analyzed in the simulations that were conducted. The furnace package that was selected was natural gas since it is predominately the most used heating fuel in Minnesota.

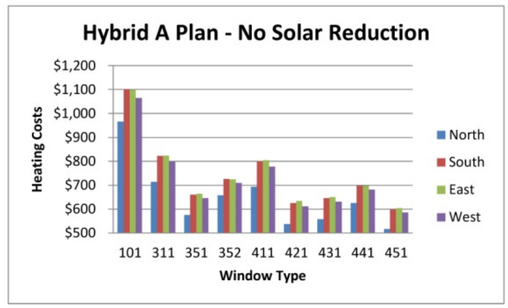
There is an option in RESFEN 5.0 where you can select the level of solar reduction that is on the home. Solar shading is a combination of exterior and interior obstructions that block sunlight. On the exterior of the home this obstructions can be trees, roof overhangs, awnings, and other houses. On the interior of the home these obstructions can be blinds, curtains, or window film. For the heating portion of the testing it was assumed that there would be no solar protection and all the sunlight would be allowed to enter the house in the winter. This information was then transferred from

RESFEN 5.0 to an excel spreadsheet. The data was then analyzed and imported into graphs to see if there were any obvious trends. The first two sets of data analyzed the annual and 30 year period of simulated heating energy consumption of the three test homes. The third set of data reviewed effects of the direction of orientation of the front of the house had on the amount of heating energy consumed. The data that was collected can be viewed in Figure 5.1, Figure 5.2, and Figure 5.3 listed below. It is important to note the difference in heating costs for the variations in orientation of the homes. The northern orientation consistently produces a lower annual heating cost. The lowest annual heating costs are found on simulations with window that had high SHGC and a high U-factor. The differences might not seem dramatic but when reviewed over an average 30 year mortgage period these difference in energy costs can reach thousands of dollars.

Standard Plan		Total Annual Heating Costs - No Solar Reduction			
Window Type	Key	Orientation of Test Home			
		North	South	East	West
101: AL Clr	101	$ 929	$ 1,005	$ 1,025	$ 996
311: w/v 2 Clear	311	$ 707	$ 771	$ 794	$ 770
351: W/V 3 HT Super	351	$ 593	$ 643	$ 659	$ 642
352: W/V 3 SS Super	352	$ 669	$ 706	$ 714	$ 702
411: Ins 2 Clear	411	$ 689	$ 752	$ 775	$ 751
421: Ins 2 PY Low E	421	$ 552	$ 607	$ 630	$ 610
431: Ins 2 SP Low-E	431	$ 577	$ 628	$ 647	$ 628
441: Ins 2 SS Low-E	441	$ 639	$ 680	$ 690	$ 676
451: Ins 3 HT Super	451	$ 544	$ 592	$ 609	$ 593



Hybrid A Plan		Total Annual Heating Costs - No Solar Reduction			
Window Type	Key	Orientation of Test Home			
		North	South	East	West
101: AL Clr	101	$ 967	$ 1,102	$ 1,099	$ 1,066
311: w/v 2 Clear	311	$ 714	$ 823	$ 825	$ 799
351: W/V 3 HT Super	351	$ 576	$ 661	$ 665	$ 646
352: W/V 3 SS Super	352	$ 659	$ 725	$ 724	$ 710
411: Ins 2 Clear	411	$ 693	$ 800	$ 804	$ 778
421: Ins 2 PY Low E	421	$ 537	$ 626	$ 635	$ 612
431: Ins 2 SP Low-E	431	$ 559	$ 646	$ 652	$ 631
441: Ins 2 SS Low-E	441	$ 626	$ 698	$ 698	$ 682
451: Ins 3 HT Super	451	$ 518	$ 599	$ 605	$ 586



Hybrid B Plan		Total Annual Heating Costs - No Solar Reduction			
Window Type	Key	Orientation of Test Home			
		North	South	East	West
101: AL Clr	101	$ 897	$ 894	$ 947	$ 922
311: w/v 2 Clear	311	$ 719	$ 715	$ 762	$ 741
351: W/V 3 HT Super	351	$ 626	$ 625	$ 659	$ 645
352: W/V 3 SS Super	352	$ 685	$ 685	$ 705	$ 685
411: Ins 2 Clear	411	$ 702	$ 700	$ 747	$ 726
421: Ins 2 PY Low E	421	$ 589	$ 588	$ 632	$ 613
431: Ins 2 SP Low-E	431	$ 613	$ 611	$ 648	$ 631
441: Ins 2 SS Low-E	441	$ 662	$ 661	$ 685	$ 673
451: Ins 3 HT Super	451	$ 586	$ 585	$ 619	$ 604

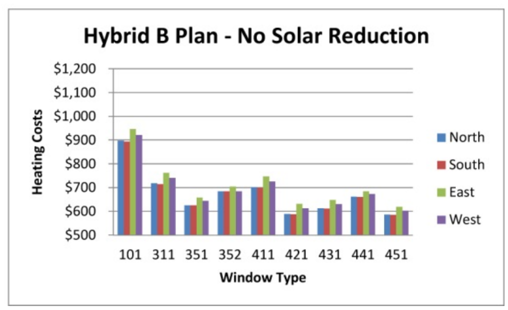
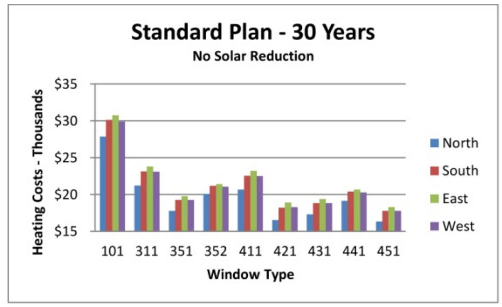
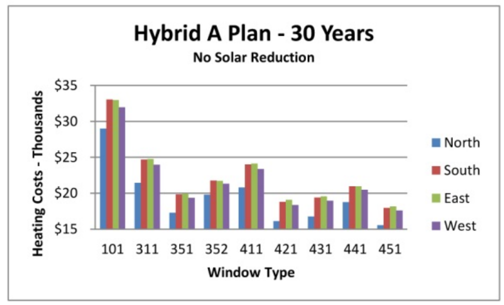


Figure 5.1. Annual Heating Cost Simulation Results

Standard Plan		30 Yr - Total Heating Costs - No Solar Reduction			
Window Type	Key	Orientation of Test Home			
		North	South	East	West
101: AL Clr	101	$ 27,866	$ 30,137	$ 30,744	$ 29,888
311: w/v 2 Clear	311	$ 21,216	$ 23,139	$ 23,806	$ 23,097
351: W/V 3 HT Super	351	$ 17,801	$ 19,287	$ 19,772	$ 19,256
352: W/V 3 SS Super	352	$ 20,074	$ 21,182	$ 21,425	$ 21,050
411: Ins 2 Clear	411	$ 20,659	$ 22,558	$ 23,236	$ 22,529
421: Ins 2 PY Low E	421	$ 16,550	$ 18,202	$ 18,915	$ 18,294
431: Ins 2 SP Low-E	431	$ 17,303	$ 18,848	$ 19,403	$ 18,848
441: Ins 2 SS Low-E	441	$ 19,158	$ 20,386	$ 20,689	$ 20,270
451: Ins 3 HT Super	451	$ 16,332	$ 17,766	$ 18,281	$ 17,778



Hybrid A - Plan		30 Yr - Total Heating Costs - No Solar Reduction			
Window Type	Key	Orientation of Test Home			
		North	South	East	West
101: AL Clr	101	$ 29,017	$ 33,068	$ 32,969	$ 31,968
311: w/v 2 Clear	311	$ 21,424	$ 24,697	$ 24,753	$ 23,972
351: W/V 3 HT Super	351	$ 17,270	$ 19,823	$ 19,946	$ 19,368
352: W/V 3 SS Super	352	$ 19,772	$ 21,764	$ 21,727	$ 21,295
411: Ins 2 Clear	411	$ 20,788	$ 24,004	$ 24,131	$ 23,351
421: Ins 2 PY Low E	421	$ 16,120	$ 18,795	$ 19,052	$ 18,368
431: Ins 2 SP Low-E	431	$ 16,757	$ 19,380	$ 19,546	$ 18,942
441: Ins 2 SS Low-E	441	$ 18,767	$ 20,945	$ 20,946	$ 20,472
451: Ins 3 HT Super	451	$ 15,529	$ 17,961	$ 18,149	$ 17,589



Hybrid B - Plan		30 Yr - Total Heating Costs - No Solar Reduction			
Window Type	Key	Orientation of Test Home			
		North	South	East	West
101: AL Clr	101	$ 26,922	$ 26,830	$ 28,420	$ 27,666
311: w/v 2 Clear	311	$ 21,572	$ 21,455	$ 22,872	$ 22,226
351: W/V 3 HT Super	351	$ 18,784	$ 18,757	$ 19,761	$ 19,356
352: W/V 3 SS Super	352	$ 20,553	$ 20,536	$ 21,163	$ 20,553
411: Ins 2 Clear	411	$ 21,057	$ 20,999	$ 22,414	$ 21,773
421: Ins 2 PY Low E	421	$ 17,681	$ 17,635	$ 18,972	$ 18,389
431: Ins 2 SP Low-E	431	$ 18,382	$ 18,344	$ 19,442	$ 18,933
441: Ins 2 SS Low-E	441	$ 19,847	$ 19,826	$ 20,558	$ 20,196
451: Ins 3 HT Super	451	$ 17,593	$ 17,563	$ 18,570	$ 18,108

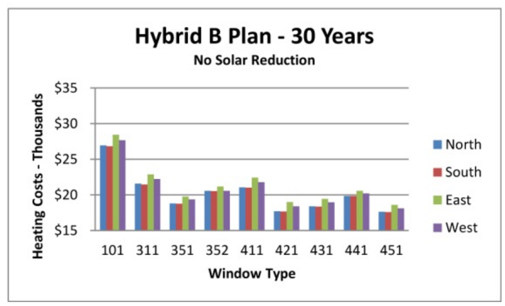
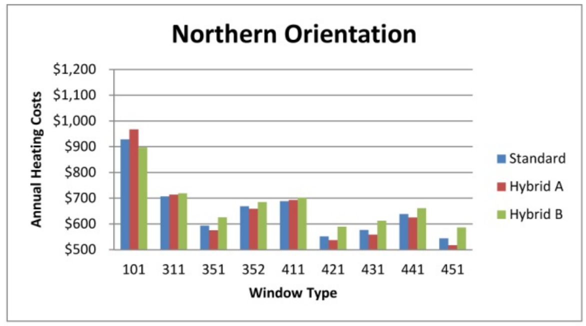
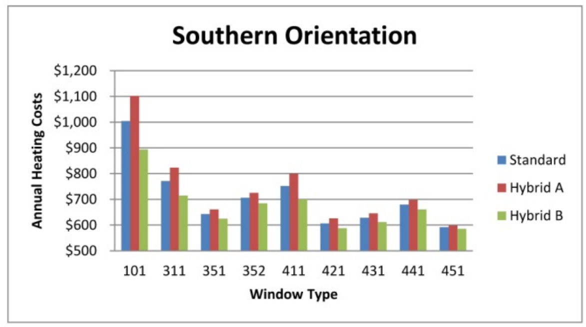


Figure 5.2. 30 Year Simulated Heating Costs

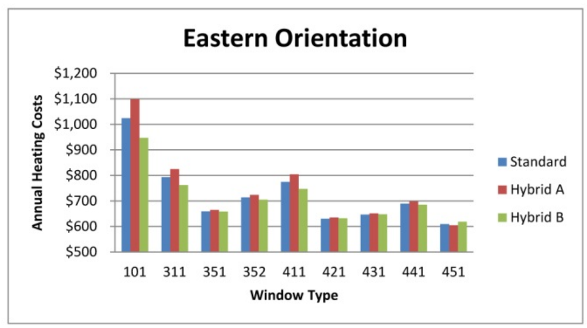
Total Annual Heating Costs - No Solar Reduction				
Home Orientation		North		
Window Type	Key	Standard	Hybrid A	Hybrid B
101: AL Clr	101	$ 929	$ 967	$ 897
311: w/v 2 Clear	311	$ 707	$ 714	$ 719
351: W/V 3 HT Super	351	$ 593	$ 576	$ 626
352: W/V 3 SS Super	352	$ 669	$ 659	$ 685
411: Ins 2 Clear	411	$ 689	$ 693	$ 702
421: Ins 2 PY Low E	421	$ 552	$ 537	$ 589
431: Ins 2 SP Low-E	431	$ 577	$ 559	$ 613
441: Ins 2 SS Low-E	441	$ 639	$ 626	$ 662
451: Ins 3 HT Super	451	$ 544	$ 518	$ 586



Total Annual Heating Costs - No Solar Reduction				
Home Orientation		South		
Window Type	Key	Standard	Hybrid A	Hybrid B
101: AL Clr	101	$ 1,005	$ 1,102	$ 894
311: w/v 2 Clear	311	$ 771	$ 823	$ 715
351: W/V 3 HT Super	351	$ 643	$ 661	$ 625
352: W/V 3 SS Super	352	$ 706	$ 725	$ 685
411: Ins 2 Clear	411	$ 752	$ 800	$ 700
421: Ins 2 PY Low E	421	$ 607	$ 626	$ 588
431: Ins 2 SP Low-E	431	$ 628	$ 646	$ 611
441: Ins 2 SS Low-E	441	$ 680	$ 698	$ 661
451: Ins 3 HT Super	451	$ 592	$ 599	$ 585



Total Annual Heating Costs - No Solar Reduction				
Home Orientation		East		
Window Type	Key	Standard	Hybrid A	Hybrid B
101: AL Clr	101	$ 1,025	$ 1,099	$ 947
311: w/v 2 Clear	311	$ 794	$ 825	$ 762
351: W/V 3 HT Super	351	$ 659	$ 665	$ 659
352: W/V 3 SS Super	352	$ 714	$ 724	$ 705
411: Ins 2 Clear	411	$ 775	$ 804	$ 747
421: Ins 2 PY Low E	421	$ 630	$ 635	$ 632
431: Ins 2 SP Low-E	431	$ 647	$ 652	$ 648
441: Ins 2 SS Low-E	441	$ 690	$ 698	$ 685
451: Ins 3 HT Super	451	$ 609	$ 605	$ 619



Total Annual Heating Costs - No Solar Reduction				
Home Orientation		West		
Window Type	Key	Standard	Hybrid A	Hybrid B
101: AL Clr	101	$ 996	$ 1,066	$ 922
311: w/v 2 Clear	311	$ 770	$ 799	$ 741
351: W/V 3 HT Super	351	$ 642	$ 646	$ 645
352: W/V 3 SS Super	352	$ 702	$ 710	$ 685
411: Ins 2 Clear	411	$ 751	$ 778	$ 726
421: Ins 2 PY Low E	421	$ 610	$ 612	$ 613
431: Ins 2 SP Low-E	431	$ 628	$ 631	$ 631
441: Ins 2 SS Low-E	441	$ 676	$ 682	$ 673
451: Ins 3 HT Super	451	$ 593	$ 586	$ 604

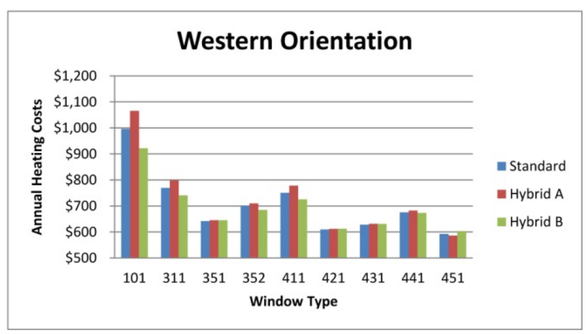
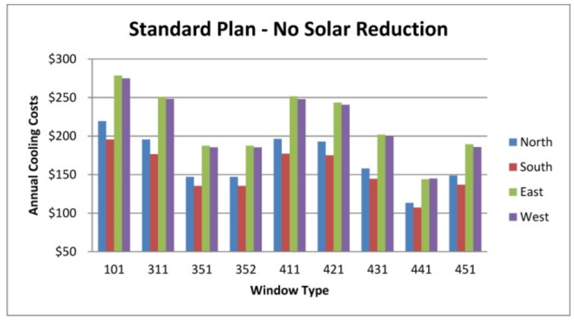


Figure 5.3. Orientation Variations Effect on Heating Energy

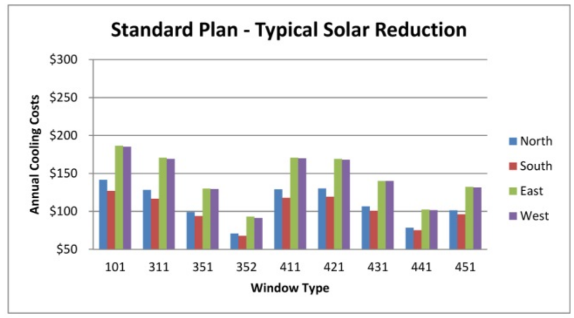
The second part of the simulation testing was focused on determining the amount of energy that is consumed on cooling the test homes during the summer months of the year. The same criteria and options that were used on heating simulation were then applied to the cooling simulations.

The unique change that was incorporated into the cooling simulations was three different levels of solar reduction. All of the test homes were simulated with no solar reductions, typical solar reduction, and full solar reduction. RESFEN 5.0's description for no solar reduction was allowing all of the sunlight to penetrate through the windows into the home during the day. RESFEN's description for typical solar reduction was utilizing interior curtains, standard overhangs, and interior blinds to block solar gain. Standard overhangs on a two story home are typically achieved by having a smaller footprint on the upper levels and having the small roof overhangs at each level. RESFEN's description for full solar reduction was utilizing obstructions such as exterior shutters, solar screens, or obstructions to block the majority of the sunlight before it could penetrate the glazing on a home. It also included the use of standard interior window coverings. The data from these simulations can be viewed in Figure 6.1, Figure 6.2, and Figure 6.3. These figures show that the difference in the SHGC of the windows can produce a dramatic variation in the total cooling costs. It is also important to note that effective solar reduction also made a large impact on overall cooling costs. The overall trends of the figures also show that greater the quantity of window area on the home the higher the annual cooling cost.

Standard Home Plan - No Solar Protection Total Annual Cooling Energy Costs					
Window Type	Key	Orientation of Test Home			
		North	South	East	West
101: AL Clr	101	$ 220	$ 196	$ 279	$ 275
311: w/v 2 Clear	311	$ 196	$ 177	$ 251	$ 248
351: W/V 3 HT Super	351	$ 147	$ 136	$ 188	$ 186
352: W/V 3 SS Super	352	$ 147	$ 136	$ 188	$ 186
411: Ins 2 Clear	411	$ 196	$ 177	$ 252	$ 248
421: Ins 2 PY Low E	421	$ 193	$ 175	$ 244	$ 241
431: Ins 2 SP Low-E	431	$ 158	$ 145	$ 202	$ 200
441: Ins 2 SS Low-E	441	$ 113	$ 107	$ 144	$ 145
451: Ins 3 HT Super	451	$ 149	$ 137	$ 190	$ 186



Standard Home Plan - Typical Solar Protection Total Annual Cooling Energy Costs					
Window Type	Key	Orientation of Test Home			
		North	South	East	West
101: AL Clr	101	$ 142	$ 127	$ 187	$ 185
311: w/v 2 Clear	311	$ 128	$ 117	$ 171	$ 169
351: W/V 3 HT Super	351	$ 99	$ 94	$ 130	$ 130
352: W/V 3 SS Super	352	$ 71	$ 68	$ 93	$ 91
411: Ins 2 Clear	411	$ 129	$ 118	$ 171	$ 170
421: Ins 2 PY Low E	421	$ 130	$ 119	$ 169	$ 168
431: Ins 2 SP Low-E	431	$ 107	$ 101	$ 140	$ 140
441: Ins 2 SS Low-E	441	$ 79	$ 75	$ 103	$ 102
451: Ins 3 HT Super	451	$ 102	$ 96	$ 132	$ 132



Standard Home Plan - Full Solar Protection Total Annual Cooling Energy Costs					
Window Type	Key	Orientation of Test Home			
		North	South	East	West
101: AL Clr	101	$ 111	$ 100	$ 154	$ 153
311: w/v 2 Clear	311	$ 101	$ 93	$ 142	$ 141
351: W/V 3 HT Super	351	$ 80	$ 76	$ 111	$ 110
352: W/V 3 SS Super	352	$ 58	$ 56	$ 79	$ 78
411: Ins 2 Clear	411	$ 101	$ 93	$ 143	$ 142
421: Ins 2 PY Low E	421	$ 102	$ 95	$ 142	$ 140
431: Ins 2 SP Low-E	431	$ 86	$ 81	$ 118	$ 117
441: Ins 2 SS Low-E	441	$ 64	$ 61	$ 88	$ 86
451: Ins 3 HT Super	451	$ 82	$ 78	$ 112	$ 111

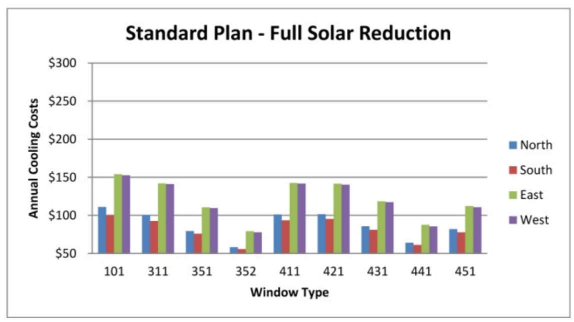
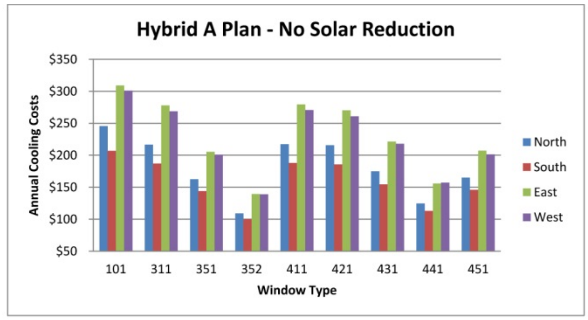
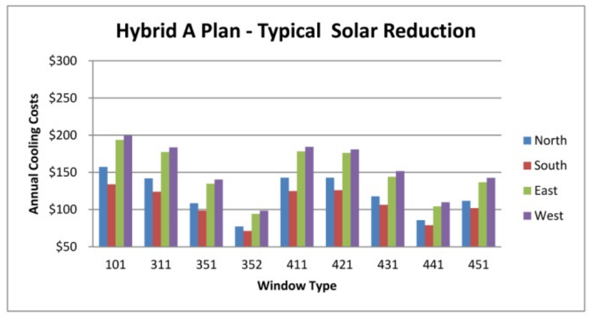


Figure 6.1. Standard Home Plan's Annual Cooling Costs

Hybrid Plan A - No Solar Protection Total Annual Cooling Energy Costs					
Window Type	Key	Orientation of Test Home			
		North	South	East	West
101: AL Clr	101	$ 246	$ 207	$ 309	$ 301
311: w/v 2 Clear	311	$ 217	$ 187	$ 278	$ 269
351: W/V 3 HT Super	351	$ 163	$ 144	$ 206	$ 201
352: W/V 3 SS Super	352	$ 109	$ 100	$ 139	$ 139
411: Ins 2 Clear	411	$ 217	$ 188	$ 280	$ 271
421: Ins 2 PY Low E	421	$ 216	$ 186	$ 270	$ 261
431: Ins 2 SP Low-E	431	$ 175	$ 155	$ 221	$ 218
441: Ins 2 SS Low-E	441	$ 125	$ 113	$ 156	$ 157
451: Ins 3 HT Super	451	$ 165	$ 146	$ 207	$ 201



Hybrid Plan A - Typical Solar Protection Total Annual Cooling Energy Costs					
Window Type	Key	Orientation of Test Home			
		North	South	East	West
101: AL Clr	101	$ 157	$ 134	$ 194	$ 200
311: w/v 2 Clear	311	$ 142	$ 124	$ 177	$ 184
351: W/V 3 HT Super	351	$ 109	$ 99	$ 135	$ 140
352: W/V 3 SS Super	352	$ 77	$ 71	$ 94	$ 98
411: Ins 2 Clear	411	$ 143	$ 125	$ 178	$ 184
421: Ins 2 PY Low E	421	$ 143	$ 126	$ 176	$ 181
431: Ins 2 SP Low-E	431	$ 118	$ 106	$ 144	$ 152
441: Ins 2 SS Low-E	441	$ 86	$ 79	$ 104	$ 110
451: Ins 3 HT Super	451	$ 112	$ 102	$ 137	$ 143



Hybrid Plan A - Full Solar Protection Total Annual Cooling Energy Costs					
Window Type	Key	Orientation of Test Home			
		North	South	East	West
101: AL Clr	101	$ 122	$ 105	$ 169	$ 167
311: w/v 2 Clear	311	$ 111	$ 98	$ 155	$ 153
351: W/V 3 HT Super	351	$ 87	$ 80	$ 121	$ 117
352: W/V 3 SS Super	352	$ 62	$ 59	$ 85	$ 83
411: Ins 2 Clear	411	$ 112	$ 99	$ 156	$ 154
421: Ins 2 PY Low E	421	$ 112	$ 101	$ 155	$ 151
431: Ins 2 SP Low-E	431	$ 93	$ 85	$ 129	$ 127
441: Ins 2 SS Low-E	441	$ 69	$ 64	$ 94	$ 92
451: Ins 3 HT Super	451	$ 89	$ 82	$ 122	$ 120

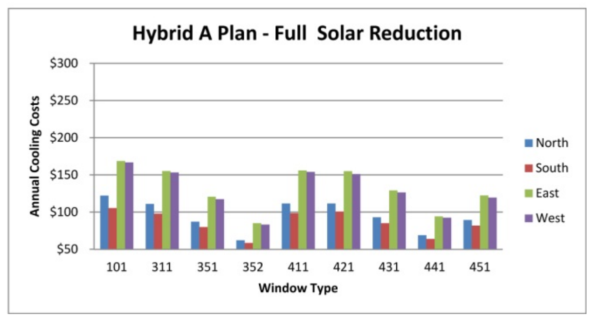
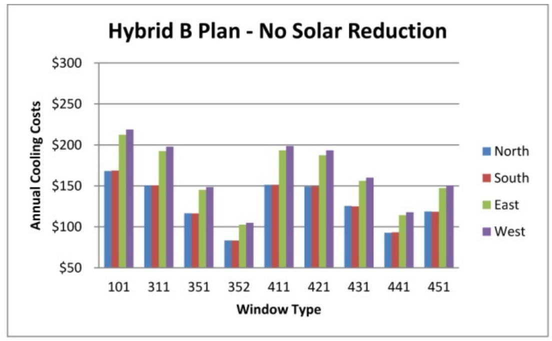
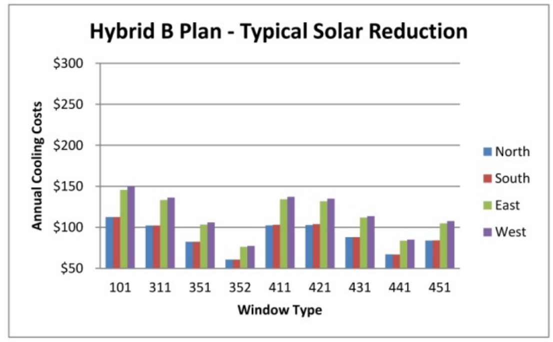


Figure 6.2. Hybrid A Home Plan's Annual Cooling Costs

Hybrid Plan B - No Solar Protection Total Annual Cooling Energy Costs					
Window Type	Key	Orientation of Test Home			
		North	South	East	West
101: AL Clr	101	$ 168	$ 169	$ 213	$ 219
311: w/v 2 Clear	311	$ 150	$ 150	$ 192	$ 198
351: W/V 3 HT Super	351	$ 117	$ 116	$ 145	$ 149
352: W/V 3 SS Super	352	$ 83	$ 83	$ 103	$ 105
411: Ins 2 Clear	411	$ 151	$ 151	$ 193	$ 199
421: Ins 2 PY Low E	421	$ 149	$ 149	$ 187	$ 193
431: Ins 2 SP Low-E	431	$ 125	$ 125	$ 156	$ 160
441: Ins 2 SS Low-E	441	$ 93	$ 93	$ 114	$ 118
451: Ins 3 HT Super	451	$ 119	$ 118	$ 147	$ 150



Hybrid Plan B - Typical Solar Protection Total Annual Cooling Energy Costs					
Window Type	Key	Orientation of Test Home			
		North	South	East	West
101: AL Clr	101	$ 112	$ 113	$ 146	$ 150
311: w/v 2 Clear	311	$ 102	$ 102	$ 133	$ 136
351: W/V 3 HT Super	351	$ 82	$ 82	$ 103	$ 106
352: W/V 3 SS Super	352	$ 61	$ 61	$ 76	$ 77
411: Ins 2 Clear	411	$ 103	$ 103	$ 134	$ 137
421: Ins 2 PY Low E	421	$ 103	$ 104	$ 132	$ 135
431: Ins 2 SP Low-E	431	$ 88	$ 88	$ 112	$ 114
441: Ins 2 SS Low-E	441	$ 67	$ 67	$ 84	$ 85
451: Ins 3 HT Super	451	$ 84	$ 84	$ 105	$ 108



Hybrid Plan B - Full Solar Protection Total Annual Cooling Energy Costs					
Window Type	Key	Orientation of Test Home			
		North	South	East	West
101: AL Clr	101	$ 88	$ 88	$ 121	$ 123
311: w/v 2 Clear	311	$ 82	$ 82	$ 112	$ 114
351: W/V 3 HT Super	351	$ 67	$ 67	$ 88	$ 89
352: W/V 3 SS Super	352	$ 51	$ 51	$ 66	$ 66
411: Ins 2 Clear	411	$ 82	$ 82	$ 112	$ 115
421: Ins 2 PY Low E	421	$ 83	$ 83	$ 112	$ 113
431: Ins 2 SP Low-E	431	$ 72	$ 71	$ 95	$ 96
441: Ins 2 SS Low-E	441	$ 55	$ 55	$ 72	$ 72
451: Ins 3 HT Super	451	$ 69	$ 69	$ 90	$ 91

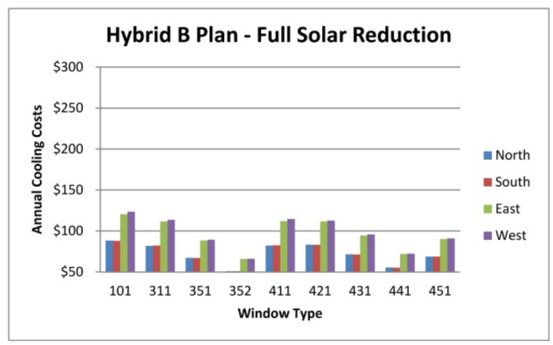


Figure 6.3. Hybrid B Home Plan's Annual Cooling Costs

The next step was to combine the heating and the cooling data in order for the total costs to be accurately analyzed. All three home designs were analyzed with the nine different windows. The orientation variable was also isolated so it could be quantified to determine the overall impact it would have on the energy costs.

The final cost breakdown includes only two window types for cost comparison purposes. The current window standard for the majority of national builders in the Minneapolis area was model 352 with a U-Factor at 0.28 and a SHGC at 0.25. The window that was selected as the best choice to test the benefits of passive solar was model 421 with a U-Factor at 0.29 and SHGC at 0.56. Window 421 was a perfect candidate to compare passive solar heat gain because it had a higher U-Value than window 352. Since window 421 had a lower level of insulation any energy consumption fluctuations would be attributable only to the SHGC value.

The Standard home plan with window 352 was compared to the Hybrid A home plan with window 421. The standard home plan assumed only typical and no solar reductions strategies. The Hybrid A home assumed full solar protection. Full solar protection would be achieved through a combination of solar screens on the outside of the home and interior window coverings on the inside of the home. The potential cost savings were then analyzed for each exposure and level of solar reduction. The maximum amount that could be saved annually by going with a Hybrid A plan and selecting a northern orientation was $253.

The construction costs of the changes were then compared to see if any additional costs or savings were incurred for the changes in the plans. Marvin Integrity and Pella Proline 450 windows were chosen as the two window brands to price for this study. The Marvin and Pella window brands are very popular in the Minneapolis area and they are used by a number of national residential builders.

The Marvin Integrity 11/16" IG LoE – 180 Argon was selected as the real life window model that had very similar performance values as the RESFEN 421 window. The Marvin model has a 0.03 higher U-Value and a 0.03 lower SHGC. The Pella Pro-line 450 11/16" Natural Sun Low-E with 2.5 mm glass was selected as a real life window model that had very similar performance to the RESFEN 421 window. This Pella window has .04 higher U-Value and a .01 higher SHGC. The Marvin Integrity 11/16" IG LoE2 – 272 Argon was selected as the real life window model that had very similar performance values as the RESFEN 352 window. This Marvin window has a 0.01 higher U-Value and a 0.03 higher SHGC. The Pella Pro-line 450 11/16" Low-E IG with Argon 2.5 mm glass was selected as a real life model that had very similar performance as the RESFEN 352 window. This Pella model has a .02 higher U–Value and a .05 higher SHGC.

Both the Marvin and the Pella windows were very similar matches to the RESFEN models and would suffice for the pricing exercise of the research. With enough time and resources an exact match for the RESFEN windows could be found but it would be very difficult to find a manufacture that produce an exact performance match in the same window line. Appendix D and E add additional information about the specifications on current Marvin Integrity and the Pella Pro-line 450 window models.

The Marvin models were then priced by a local lumber yard in the Minneapolis area. The Pella models were priced by Lowes, a national home improvement store. These unit prices were then used to calculate the construction costs to increase the glazing area on the home plans. The standard home plan's glazing area was priced using the most common window being used by the national residential builders. Those windows were Marvin LoE2 – 272 Argon and Pella Proline 450 Low-E IG Argon. The Hybrid A plan's glazing area was priced up using the windows with high SHGC. Those windows were the Marvin LoE – 180 Argon and the Pella Proline 450 Natural Sun Low E windows. See Appendix A and B for pricing information on the Marvin Integrity and Pella Pro-line window models.

The window pricing that was returned on the Marvin windows by the lumber yard had some interesting trends with pricing on the windows. The specialized coatings that are designed to reduce solar heat gain create a unique variable in the window pricing. The LoE 272 coating is the most popular coating currently being produced by Marvin and is being used in the Minneapolis area. Due to manufacture scales of economy this is the least expensive coating to purchase on a window. The price to switch to a high SHGC window was approximately 9% more expensive than the standard window currently being used in the industry.

The Marvin windows were $1,723 more expensive to change to a higher SHGC model. The highest estimated annual savings in energy by using high SHGC windows is $253. Once the solar shading features are equipped the shortest payback period is 8.5 years. Some homeowners would find this acceptable but 8.5 years is a long time to wait for an investment to pay for itself. Other window models were priced to see if a less expensive option could found with a shorter payback period.

The window pricing that was returned by Lowes on the Pella windows were more in line with the assumed manufacturing costs. The Pella windows with a high SHGC ranged from being slightly less expensive to approximately 2.5% more expensive depending on window models. Pella has twice as many manufacturing facilities as Marvin and due to that reason the cost of the high SHGC window might be more in line with the actual production costs.

Due to the competitive pricing, Pella was selected as the manufacture that would be used to calculate construction costs and payback periods. The Hybrid A home plan with an increase of 267 SF total square footage of windows that were all priced with Pella high SHGC windows and came to $6,800. The standard home plan with the current industry standard Pella windows was priced at $8,945. To get the window opening quantity closer to the actual amount on the standard home some larger windows were priced on the Hybrid A home plan. The larger Pella windows with the high SHGC were priced for the Hybrid A home plan and the total was $6,580. The total savings by going with the Hybrid A plan with 67 more square feet of high SHGC window was $220.

The installation and framing costs to add the additional glazing area were ignored. This was due to the fact the number window openings would most likely be reduced even though the glazing area would increase. The same or fewer number of window openings would need to be framed and the same or fewer number of windows would need to be set. Since the overall width of the window was not drastically changing it was assumed that the typically header material would still be utilized and additional lumber costs could be avoided. This basically put all the additional cost to increase the glazing area into the cost of the window.

After all the solar shading options were analyzed and researched, the only one that seemed to be a viable candidate for wide spread adoption were solar screens. The solar shading system would need to be operable to allow passive solar heating to occur in the winter and able to block sunlight in the summer months. The standard new construction home in Minneapolis is a two story so an roof overhang is not effective to block sunlight on the lower levels. The design of the house also plays a key role in use of a roof overhang. A hip style roof would allow for the second story roof overhang to be increased to block summer sunlight and allow winter sunlight to penetrate into the windows. On a traditional gable style roof there back of the home would not allow for any roof overhang extension. The test home has a traditional gable style roof but there is a small roof extension that could be used as a shading feature. This starts to get very complicated and not much shading is produced as a result.

Due to the variation in home designs, window sizes, window placement, and orientation, an option that attached to each window seemed like the most logical way to reduce solar heat gain. There are many different shading systems and designs that are currently being utilized in residential construction.

Awnings are one solution that has been used effectively to reduce solar heat gain. Awnings can be retracted in the winter to allow sunlight to penetrate in to the window. Then the awnings can then be extended in the summer to block the higher angled sun. Awnings are bold statement on any home and it is likely that some homeowners would be appose to installing awning on the exterior of their home. The awnings that were quoted for the study were between $200 and $250. This price was did not include installation which could range from dramatically due to window location. Considering the yearly energy savings is $250 for every awnings installed it would increase the payback period by an additional year. A more cost effective solution would need to be found to provide summer shading.

Solar screens are a very simple way to achieve effective solar shading. Solar screens can be applied across the residential construction spectrum to just about any home for about the same cost. Currently solar screen material is not being utilized in the new construction market in Minneapolis, Minnesota. The solar screen material that was selected was Phifer Suntex 90. This screening material is widely available at national home improvement centers and could easily be adopted on the large scale basis. Phifer

Suntex 90 has testing data showing that a 0.08 shading coefficient can be achieved by utilizing their solar screen product. See Appendix C for Phifer Suntex 90 specifications and pricing information. Suntex 90 solar screens can be inserted into a home's existing window screen frames. The material was priced and installation labor was added to the breakdown. The Suntex solar screens were only priced to be installed on the southern side of the home. The price to purchase the material and replace the current window screens on the south side of the home came $461 dollars. In order for homeowners to maximize the passive solar heat gains and heat reduction the Suntex solar screens would need to be installed in spring and removed in the fall.

The Suntex solar screen material combined with the interior shades and curtains would achieve RESFEN's description for full solar reduction. This option was then added to the total construction cost of the Hybrid A plan equipped with Pella high SHGC windows. The total cost to change the home plan and implement the passive heating and cooling recommendations would be a cost of $241 dollars. The total construction cost and energy comparison for both the Marvin and Pella windows can be viewed on Figure 7.1 and 7.2 listed below. The difference in cost of the Pella versus Marvin windows made a dramatic difference in the payback periods for the high SHGC windows and implementation of the solar screens.

Current National Home Builder Standard Plan -1				
Window Type	No Solar Protection			
352: W/V 3 SS Super	North	South	East	West
Heating Costs	$ 669	$ 706	$ 714	$ 702
Cooling Costs	$ 147	$ 136	$ 188	$ 186
Total Annual Energy Cost	$ 816	$ 842	$ 902	$ 887

Current National Home Builder Standard Plan - 2				
Window Type	Cooling - Typical Solar Protection			
352: W/V 3 SS Super	North	South	East	West
Heating Costs (No Solar Prot.)	$ 669	$ 706	$ 714	$ 702
Cooling Costs (Typical Solar Pro.)	$ 71	$ 68	$ 93	$ 91
Total Annual Energy Cost	$ 740	$ 774	$ 807	$ 793

Recommendation Home Type - Hybrid A				
Window Type	Full Solar Protection			
421: Ins 2 PY Low E	North	South	East	West
Heating Costs	$ 537	$ 626	$ 635	$ 612
Cooling Costs	$ 112	$ 101	$ 155	$ 151
Total Annual Energy Cost	$ 649	$ 727	$ 790	$ 764

Annual Energy Comparison				
House Type	Total Annual Energy Usage			
	North	South	East	West
Standard - No Solar Protection	$ 816	$ 842	$ 902	$ 887
Standard - Typical Solar Protection	$ 740	$ 774	$ 807	$ 793
Hybrid A - Full Solar Protection	$ 649	$ 727	$ 790	$ 764

Annual Savings with Same Orientation				
House Type	Total Annual Energy Usage			
	North	South	East	West
Standard - No Solar Protection	$ -	$ -	$ -	$ -
Standard - Typical Solar Protection	$ 76	$ 68	$ 94	$ 94
Hybrid A - Full Solar Protection	$ 167	$ 114	$ 112	$ 124

Maximum Savings with Northern Orientation				
House Type	Total Annual Energy Usage			
	North	South	East	West
Standard - No Solar Protection	$ 85	$ 60	$ -	$ 15
Standard - Typical Solar Protection	$ 162	$ 128	$ 94	$ 109
Hybrid A - Full Solar Protection	$ 253	$ 174	$ 112	$ 138

Current National Home Plan Window Costs				
Window Type Model Priced: Marvin Integrity LOE 272 Argon				
Simulated Window Type: 352: W/V 3 SS Super				
Glazing Area (SF)	Window Size	Window Quantity	Window Price	Total Cost
200	12	16.67	$ 427	$ 7,117
200	15	13.33	$ 478	$ 6,373
200	22.17	9.02	$ 666	$ 6,008

Hybrid A Home Plan's Window Costs				
Window Type Model Priced: Marvin Integrity LOE 180 Argon				
Simulation Window Type: 421: Ins 2 PY Low E				
Glazing Area (SF)	Window Size (SF)	Window Quantity	Window Price	Total Cost
267	12	22.25	$ 464	$ 10,324
267	15	17.80	$ 524	$ 9,327
267	22.17	12.04	$ 734	$ 8,840

Phifer Suntex 90 - Solar Screen Costs			
Roll Size (SF)	Price	Installation Cost	Total Cost
300	$ 211	$ 250	$ 461

Construction Cost Savings Breakdown				
Home Plan:	Standard	Hybrid A	Solar Screen Cost	Total Added Cost
Window Size	Window Cost	Window Cost		
36" x 48"	$ 7,117	$ 10,324	$ 461	$ 3,668
36" x 60"	$ 6,373	$ 9,327	$ 461	$ 3,415
42" x 76"	$ 6,008	$ 8,840	$ 461	$ 3,293
12 SF to 22 SF	$ 7,117	$ 8,840	$ 461	$ 2,184

Construction Cost	Annual Savings	Payback Period
$ 2,184	253	$ 8.63

Figure 7.1. Construction Costs and Payback Summary – Marvin Windows

Current National Home Builder Standard Plan -1				
Window Type	No Solar Protection			
352: W/V 3 SS Super	North	South	East	West
Heating Costs	$ 669	$ 706	$ 714	$ 702
Cooling Costs	$ 147	$ 136	$ 188	$ 186
Total Annual Energy Cost	$ 816	$ 842	$ 902	$ 887

Current National Home Builder Standard Plan - 2				
Window Type	Cooling - Typical Solar Protection			
352: W/V 3 SS Super	North	South	East	West
Heating Costs (No Solar Prot.)	$ 669	$ 706	$ 714	$ 702
Cooling Costs (Typical Solar Pro.)	$ 71	$ 68	$ 93	$ 91
Total Annual Energy Cost	$ 740	$ 774	$ 807	$ 793

Recommendation Home Type - Hybrid A				
Window Type	Full Solar Protection			
421: Ins 2 PY Low E	North	South	East	West
Heating Costs	$ 537	$ 626	$ 635	$ 612
Cooling Costs	$ 112	$ 101	$ 155	$ 151
Total Annual Energy Cost	$ 649	$ 727	$ 790	$ 764

Annual Energy Comparison				
House Type	Total Annual Energy Usage			
	North	South	East	West
Standard - No Solar Protection	$ 816	$ 842	$ 902	$ 887
Standard - Typical Solar Protection	$ 740	$ 774	$ 807	$ 793
Hybrid A - Full Solar Protection	$ 649	$ 727	$ 790	$ 764

Annual Savings with Same Orientation				
House Type	Total Annual Energy Usage			
	North	South	East	West
Standard - No Solar Protection	$ -	$ -	$ -	$ -
Standard - Typical Solar Protection	$ 76	$ 68	$ 94	$ 94
Hybrid A - Full Solar Protection	$ 167	$ 114	$ 112	$ 124

Maximum Savings with Northern Orientation				
House Type	Total Annual Energy Usage			
	North	South	East	West
Standard - No Solar Protection	$ 85	$ 60	$ -	$ 15
Standard - Typical Solar Protection	$ 162	$ 128	$ 94	$ 109
Hybrid A - Full Solar Protection	$ 253	$ 174	$ 112	$ 138

Current National Home Plan Window Costs				
Pella Proline 450 - 11/16" Low-E IG with Argon 2.5 mm Glass				
Simulated Window Type: 352: W/V 3 SS Super				
Glazing Area (SF)	Window Size	Window Quantity	Window Price	Total Cost
200	12	16.67	$ 408	$ 6,800
200	15	13.33	$ 363	$ 4,840
200	28	7.14	$ 673	$ 4,807

Hybrid A Home Plan's Window Costs				
Pella Proline 450- 11/16" Natural Sun Low-E IG with 2.5 mm Glass				
Simulation Window Type: 421: Ins 2 PY Low E				
Glazing Area (SF)	Window Size (SF)	Window Quantity	Window Price	Total Cost
267	12	22.25	$ 402	$ 8,945
Na	NA	NA	NA	NA
267	28	9.54	$ 690	$ 6,580

Phifer Suntex 90 - Solar Screen Costs			
Roll Size (SF)	Price	Installation Cost	Total Cost
300	$ 211	$ 250	$ 461

Construction Cost Savings Breakdown				
Home Plan:	Standard	Hybrid A	Solar Screen Cost	Total Added Cost
Window Size	Window Cost	Window Cost		
36" x 48"	$ 6,800	$ 8,945	$ 461	$ 2,606
36" x 60"	$ 4,840	NA	NA	NA
48" x 84"	$ 4,807	$ 6,580	$ 461	$ 2,234
12 SF to 22 SF	$ 6,800	$ 6,580	$ 461	$ 241

Construction Cost	Annual Savings	Payback Period
$ 241	253	$ 0.95

Figure 7.2. Construction Costs and Payback Summary – Pella Windows

Conclusion

There are many factors that could affect the amount of heating and cooling energy consumed by residential homes. This study analyzed a single model home plan from a national home builder. The potential energy savings were calculated using RESFEN 5.0 energy modeling program. The simulated energy modeling only tested the variables of glazing area, glazing types, solar shading, and orientation.

The testing data results were also based on the occupants of the home taking steps to achieve certain levels of solar reduction. These steps included installing solar screens in the spring and removing them in the fall. It was also assumed that window curtains and shades would need to be drawn during the day in the summer to reduce the heat generated by the sun. In the winter the occupants would need to keep the curtains and shades open during the day to allow sunlight to penetrate into the home. Additional insulation benefits could be achieved in the winter if all of the window shades were closed at night to add some level of insulation and reduce heat loss.

The standard national homebuilder's plan with the standard window was simulated to gauge the amount of influence a homeowner could have. The home was simulated with full solar protection and no solar protection. The best case scenario was orientating the home so the majority of the glazing area faced south. Using the standard building plan with the standard windows the most a homeowner could save each year by opening and closing window coverings was \$100. If the window coverings were ignored the difference in heating and cooling would be plus or minus \$20. If the homeowner did not operate the window coverings on the Hybrid A home plan with high SHGC windows a similar result occurred. The difference in energy savings would be plus or minus \$8. If the homeowner followed the correct behavior for maximizing passive solar then savings could be up to \$253 per year.

The data that was collect during the simulations concluded that the orientation of the home played a key role in reducing the overall energy consumption. The best orientation to maximize solar heat gain in Minneapolis is due south. The glazing type and quantity of glazing played an equally important role in reducing the energy consumption.

In this particular case the construction costs to increase the glazing area and achieve a higher SHGC of the windows came out to be a cost decrease. It was assumed that the average window size would be increased to accommodate the larger amount of glazing that was being added to the plan. The added cost was attributed to changing out the existing screen material with a solar screen material. This only added $241 to the total construction cost of the home and it produced the added benefit of having an additional 67 square feet of windows.

The annual savings that was achieved varied depending on the orientation of the home. The largest cost savings that could be achieved was by orientating the home to the north so the majority of the glazing would face south. The cost savings by orientating the home to the north and installing high SHGC windows was $253 per year.

This yearly cost savings in energy reduction might not seem like much but it is a step in the right direction. That savings assumes that the current cost of energy remains the same. Energy costs are steadily increasing for the last decade and it is safe to assume that even more money will be saved as energy prices continue to climb.

This direct study was evidence, based on a simulated study, that in Minneapolis a national home builder's standard home plan can be modestly modified to effectively implement passive solar design features. It is important for homeowners to see the value of a home with the majority of the windows facing south. The overall energy consumption is reduced by increasing the southern window area and changing the windows to a high SHGC model. Solar screens are required to reduce the solar heat gain during the summer months. Typically implementing solar screens will pay for themselves in two to three years in cooling energy savings in the Minneapolis area. These energy savings assume some level of homeowner action to install and remove window screens along with opening and closing the window coverings.

The results produced by this project's simulations show that passive solar strategies can be successful implemented on a current home plan from a national home builder in Minneapolis, Minnesota. The cost savings are modest but so are the changes that the home builders will need to make to implement the changes. This could be the first step in getting passive solar technologies into the main stream residential construction markets. This modest yearly savings might be enough the spark home buyer's interest and start the trend of requesting passive solar designs and the majority of windows facing orientated to the south on an average home. Developers might also see the benefits in taking extra time to adjust their residential developments allow for the larger facades of the homes to face due north or south. Developers could start using passive solar orientation as a selling point to help distinguish their lots and increase sales.

If homeowners or builder are interested in reproducing these results the steps are very easy. RESFEN 5.0 is free software that can be downloaded from the internet. Homeowner can either enter in the data from a new home plan or they can enter in data from their existing homes. The data that needs to be entered for the home characteristics are very simple only take a few minutes upload. Then different amounts of glazing area and window types can be selected to determine energy implications. This would be a good exercise for any homeowner who is thinking about replacing some windows or trying to determine which windows to use on their new home. Even a small step toward passive solar design can become a big reduction in energy consumption over the lifetime of a home.

The next step to move this research forward would be to find an effective way to bring the information provided in this paper to the main stream public. One possible next step would be to develop a test home that will put these passive solar changes on display. The key would be finding a northern facing lot in a development that was currently constructed. The test home could be built and then it could be used a showcase home to display what needs to take place to make passive solar work in standard residential construction.

Right now the national home builders are extremely competitive and are looking for features and benefits that distinguish them from the competition. One approach to getting the test home built would be to approach a national home builder with the concept. It is very little exposure for the national home builder because it only costs an additional $250 dollars to implement all the passive solar changes to the home. The home builder could then use this home to promote themselves as green builder and a leading innovator in the market.

Another option to move this research forward would be to go directly to homeowners with the knowledge. A website could be developed that explains the research and how to reproduce the results on an actual home. There are also several major home remodeling shows in the Minneapolis area. A good option would be to set up a small booth at one of these events and explain the results of the simulations to homeowners. Homeowner's could be taught how to do the energy simulations themselves using RESFEN 5.0 or that service could be offered to be performed for free. The whole goal would be getting the information directly to the homeowners and making them realize what possibilities are out there.

These two options would be the next logical step to move this research to the next level and validate the simulated data. Once the simulation has been validated it will be more likely to become a standard building practice and something that will change then entire industry. The energy savings should get more dramatic as the cost of electricity and natural gas continue to rise. This research might also gain some traction as homeowner start to look for alternatives to save money on their heating and cooling bills.

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Appendix A

MARVIN Windows and Doors
Built around you.

luke albers thesis project
luke albers thesis project 11-01-2011

Bill To:
SCHERER BROTHERS LUMBER CO.
9TH AVE. N.E. & MISS RIVER
MINNEAPOLIS, MN 55413

Ship To:
SCHERER BROTHERS LUMBER CO.
4797 HIGHWAY 10
ARDEN HILLS, MN 55112

Req. Ship Date:
Ship Via: OUR TRUCK
P.O.:

Contact: DON ROEHL
Phone: (612) 627-0634

Sold By: DON ROEHL

Purchaser: LUKE ALBERS

,
( ) -

GBG is not available w/Obscure glass
SDL spacer only available in 366 Glass
all obcure Glass is Tempered

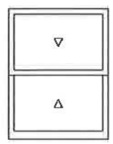
luke albers thesis project

Version 8.111 11/01/11 PAGE 1

*** PRICES LISTED IN USD ***

QUOTE: 00000001

QTY: 1 MARK UNIT - LOE-180 ARGON	
INTEGRITY TRAD`L DOUBLE HUNG	406.00
WOOD INTERIOR - ULTREX EXTERIOR SERIES	
CALL NUMBER 3648	
ROUGH OPENING 36 1/2" X 48 1/4"	
INSULATED GLASS - 1 LITE	
LoE-180 WITH ARGON	37.00
ALMOND FROST SASH LOCK	0.00
SCREEN	21.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00
NAILING FIN	0.00
4 9/16" JAMBS	0.00
BARE PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	464.00



AS VIEWED FROM THE EXTERIOR

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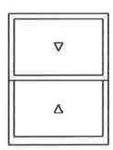
INTEGRITY TRAD`L DOUBLE HUNG	406.00
WOOD INTERIOR - ULTREX EXTERIOR SERIES	
CALL NUMBER 3648	
ROUGH OPENING 36 1/2" X 48 1/4"	
INSULATED GLASS - 1 LITE	
TEMPERED LoE-180 OBSCURE WITH ARGON	221.00
ALMOND FROST SASH LOCK	0.00
SCREEN	21.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00
NAILING FIN	0.00
4 9/16" JAMBS	0.00
BARE PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	648.00



AS VIEWED FROM THE EXTERIOR

QUOTE: 00000003

QTY: 1 MARK UNIT - LOE-180 ARG OBSC SDL TEMP

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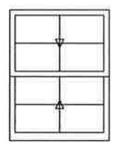
*** PRICES LISTED IN USD ***

INTEGRITY TRAD`L DOUBLE HUNG	406.00
WOOD INTERIOR - ULTREX EXTERIOR SERIES	
CALL NUMBER 3648	
ROUGH OPENING 36 1/2" X 48 1/4"	
INSULATED GLASS - 1 LITE	
TEMPERED LoE-180 OBSCURE WITH ARGON	221.00
7/8" RECTANGULAR SIMULATED DIVIDED LITE - NO SPACER BAR - STANDARD	
CUT 2-WIDE 2-HIGH	144.00
STONE WHITE EXTERIOR - BARE PINE INTERIOR	0.00
ALMOND FROST SASH LOCK	0.00
SCREEN	21.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00
NAILING FIN	0.00
4 9/16" JAMBS	0.00
BARE PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	792.00



AS VIEWED FROM THE EXTERIOR

DIVIDED LITE CUT ALIGNMENT MAY NOT BE ACCURATELY REPRESENTED IN THE MQS GENERATED DRAWING
PLEASE CONSULT YOUR LOCAL INTEGRITY REPRESENTATIVE FOR EXACT SPECIFICATIONS

QUOTE: 00000004
QTY: 1 MARK UNIT - LOE-180 ARG GBG TEMP

INTEGRITY TRAD`L DOUBLE HUNG	406.00
WOOD INTERIOR - ULTREX EXTERIOR SERIES	
CALL NUMBER 3648	
ROUGH OPENING 36 1/2" X 48 1/4"	
INSULATED GLASS - 1 LITE	
LOW E II WITH ARGON	0.00
7/8" RECTANGULAR SIMULATED DIVIDED LITE - NO SPACER BAR - STANDARD	
CUT 2-WIDE 2-HIGH	144.00
STONE WHITE EXTERIOR - BARE PINE INTERIOR	0.00
ALMOND FROST SASH LOCK	0.00
SCREEN	21.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00
NAILING FIN	0.00
4 9/16" JAMBS	0.00
BARE PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	571.00

QUOTE CONTINUED ON NEXT PAGE.

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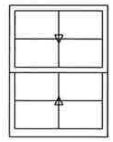

AS VIEWED FROM THE EXTERIOR

DIVIDED LITE CUT ALIGNMENT MAY NOT BE ACCURATELY REPRESENTED IN THE MQS GENERATED DRAWING
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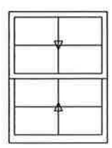
QUOTE: 00000005

QTY: 1 MARK UNIT - LOE-272 ARG SDL OBSC	
INTEGRITY TRAD`L DOUBLE HUNG	406.00
WOOD INTERIOR - ULTREX EXTERIOR SERIES	
CALL NUMBER 3648	
ROUGH OPENING 36 1/2" X 48 1/4"	
INSULATED GLASS - 1 LITE	
TEMPERED LOW E II OBSCURE WITH ARGON	202.00
7/8" RECTANGULAR SIMULATED DIVIDED LITE - NO SPACER BAR - STANDARD	
CUT 2-WIDE 2-HIGH	144.00
STONE WHITE EXTERIOR - BARE PINE INTERIOR	0.00
ALMOND FROST SASH LOCK	0.00
SCREEN	21.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00
NAILING FIN	0.00
4 9/16" JAMBS	0.00
BARE PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	773.00



AS VIEWED FROM THE EXTERIOR

DIVIDED LITE CUT ALIGNMENT MAY NOT BE ACCURATELY REPRESENTED IN THE MQS GENERATED DRAWING
PLEASE CONSULT YOUR LOCAL INTEGRITY REPRESENTATIVE FOR EXACT SPECIFICATIONS

QUOTE: 00000006

QTY: 1 MARK UNIT - LOE-272 ARG OBSC	
INTEGRITY TRAD`L DOUBLE HUNG	406.00
WOOD INTERIOR - ULTREX EXTERIOR SERIES	
CALL NUMBER 3648	
ROUGH OPENING 36 1/2" X 48 1/4"	
INSULATED GLASS - 1 LITE	
TEMPERED LOW E II OBSCURE WITH ARGON	202.00
ALMOND FROST SASH LOCK	0.00
SCREEN	21.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00

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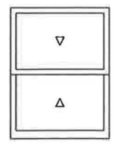
*** PRICES LISTED IN USD ***

NAILING FIN	0.00
4 9/16" JAMBS	0.00
BARE PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	629.00



AS VIEWED FROM THE EXTERIOR

QUOTE: 00000007

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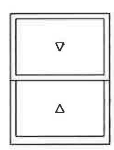
INTEGRITY TRAD`L DOUBLE HUNG	406.00
WOOD INTERIOR - ULTREX EXTERIOR SERIES	
CALL NUMBER 3648	
ROUGH OPENING 36 1/2" X 48 1/4"	
INSULATED GLASS - 1 LITE	
TEMPERED LOW E II WITH ARGON	143.00
ALMOND FROST SASH LOCK	0.00
SCREEN	21.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00
NAILING FIN	0.00
4 9/16" JAMBS	0.00
BARE PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	570.00



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INTEGRITY TRAD`L DOUBLE HUNG	406.00
WOOD INTERIOR - ULTREX EXTERIOR SERIES	
CALL NUMBER 3648	
ROUGH OPENING 36 1/2" X 48 1/4"	
INSULATED GLASS - 1 LITE	
TEMPERED LoE-366 OBSCURE WITH ARGON	221.00
ALMOND FROST SASH LOCK	0.00
SCREEN	21.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00

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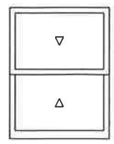
luke albers thesis project

Version 8.111 11/01/11 PAGE 5

*** PRICES LISTED IN USD ***

NAILING FIN	0.00
4 9/16" JAMBS	0.00
BARE PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	648.00



AS VIEWED FROM THE EXTERIOR

QUOTE: 00000009
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INTEGRITY TRAD`L DOUBLE HUNG	406.00
WOOD INTERIOR - ULTREX EXTERIOR SERIES	
CALL NUMBER 3648	
ROUGH OPENING 36 1/2" X 48 1/4"	
INSULATED GLASS - 1 LITE	
TEMPERED LoE-366 WITH ARGON	161.00
RECTANGULAR GRILLE BETWEEN GLASS - WHITE INTERIOR / STONE WHITE EXTERI - STANDARD CUT 2-WIDE 2-HIGH	56.00
ALMOND FROST SASH LOCK	0.00
SCREEN	21.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00
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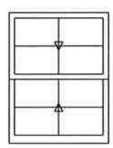
BARE PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	644.00



AS VIEWED FROM THE EXTERIOR

DIVIDED LITE CUT ALIGNMENT MAY NOT BE ACCURATELY REPRESENTED IN THE MQS GENERATED DRAWING
PLEASE CONSULT YOUR LOCAL INTEGRITY REPRESENTATIVE FOR EXACT SPECIFICATIONS

QUOTE: 00000010
QTY: 1   MARK UNIT - LOE-366 ARG TEMP W/SDL

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Version 8.111 11/01/11 PAGE 6

*** PRICES LISTED IN USD ***

INTEGRITY TRAD`L DOUBLE HUNG	406.00
WOOD INTERIOR - ULTREX EXTERIOR SERIES	
CALL NUMBER 3648	
ROUGH OPENING 36 1/2" X 48 1/4"	
INSULATED GLASS - 1 LITE	
TEMPERED LoE-366 WITH ARGON	161.00
7/8" RECTANGULAR SIMULATED DIVIDED LITE - NO SPACER BAR - STANDARD CUT 2-WIDE 2-HIGH	144.00
STONE WHITE EXTERIOR - BARE PINE INTERIOR	0.00
ALMOND FROST SASH LOCK	0.00
SCREEN	21.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00
NAILING FIN	0.00
4 9/16" JAMBS	0.00
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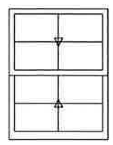
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	732.00



AS VIEWED FROM THE EXTERIOR

DIVIDED LITE CUT ALIGNMENT MAY NOT BE ACCURATELY REPRESENTED IN THE MQS GENERATED DRAWING
PLEASE CONSULT YOUR LOCAL INTEGRITY REPRESENTATIVE FOR EXACT SPECIFICATIONS

QUOTE: 00000011
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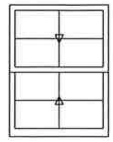
INTEGRITY TRAD`L DOUBLE HUNG	406.00
WOOD INTERIOR - ULTREX EXTERIOR SERIES	
CALL NUMBER 3648	
ROUGH OPENING 36 1/2" X 48 1/4"	
INSULATED GLASS - 1 LITE	
TEMPERED LoE-366 WITH ARGON	161.00
7/8" RECTANGULAR SIMULATED DIVIDED LITE - WITH SPACER BAR - STANDARD CUT 2-WIDE 2-HIGH	208.00
STONE WHITE EXTERIOR - BARE PINE INTERIOR	0.00
ALMOND FROST SASH LOCK	0.00
SCREEN	21.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00
NAILING FIN	0.00
4 9/16" JAMBS	0.00
BARE PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	796.00

QUOTE CONTINUED ON NEXT PAGE.

Version 8.111 11/01/11 **luke albers thesis project** PAGE 7

*** PRICES LISTED IN USD ***



AS VIEWED FROM THE EXTERIOR

DIVIDED LITE CUT ALIGNMENT MAY NOT BE ACCURATELY REPRESENTED IN THE MQS GENERATED DRAWING
PLEASE CONSULT YOUR LOCAL INTEGRITY REPRESENTATIVE FOR EXACT SPECIFICATIONS

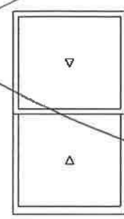
PROJECT TOTAL PRICE: 7,267.00

luke albers thesis project

Version 8.111 11/04/11 PAGE 9

*** PRICES LISTED IN USD ***

NAILING FIN	0.00
4 9/16" JAMBS	0.00
BARE PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	1,038.00



AS VIEWED FROM THE EXTERIOR

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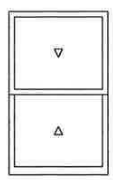
INTEGRITY TRAD`L DOUBLE HUNG	456.00
WOOD INTERIOR - ULTREX EXTERIOR SERIES	
CALL NUMBER 3660	
ROUGH OPENING 36 1/2" X 60 1/4"	
INSULATED GLASS - 1 LITE	
LOW E II WITH ARGON	0.00
ALMOND FROST SASH LOCK	0.00
SCREEN	22.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00
NAILING FIN	0.00
4 9/16" JAMBS	0.00
BARE PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	478.00



AS VIEWED FROM THE EXTERIOR

QUOTE: 00000017
QTY: 1 MARK UNIT -

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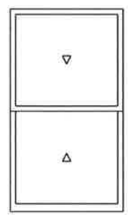
Version 8.111 11/04/11 PAGE 10

*** PRICES LISTED IN USD ***

INTEGRITY TRAD`L DOUBLE HUNG	632.00
WOOD INTERIOR - ULTREX EXTERIOR SERIES	
CALL NUMBER 4276	
ROUGH OPENING 42 1/2" X 76 1/4"	
INSULATED GLASS - 1 LITE	
LOW E II WITH ARGON	0.00
ALMOND FROST SASH LOCK	0.00
SCREEN	34.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00
NAILING FIN	0.00
4 9/16" JAMBS	0.00
BARE PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	666.00

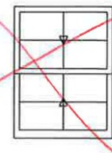


AS VIEWED FROM THE EXTERIOR

PROJECT TOTAL PRICE: 11,438.00

Version 8.111 11/03/11 **luke albers thesis project** PAGE 7

*** PRICES LISTED IN USD ***



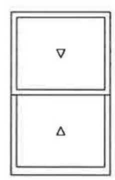
AS VIEWED FROM THE EXTERIOR

DIVIDED LITE CUT ALIGNMENT MAY NOT BE ACCURATELY REPRESENTED IN THE MQS GENERATED DRAWING
PLEASE CONSULT YOUR LOCAL INTEGRITY REPRESENTATIVE FOR EXACT SPECIFICATIONS

QUOTE: 00000012
QTY: 1 MARK UNIT -

I TDH	456.00
WOOD - ULTREX SERIES	
CN 3660	
RO 36 1/2" X 60 1/4"	
IG - 1 LITE	
LoE-180 W/ARGON	46.00
AF SASH LOCK	0.00
SCREEN	22.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00
NAILING FIN	0.00
4 9/16" JAMBS	0.00
BA PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	524.00

15 Sq ft



AS VIEWED FROM THE EXTERIOR

QUOTE: 00000013
QTY: 1 MARK UNIT -

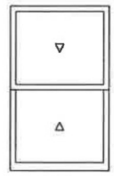
I TDH	456.00
WOOD - ULTREX SERIES	
CN 3660	
RO 36 1/2" X 60 1/4"	
IG - 1 LITE	
TEMP LOW E II OBSCURE W/ARG	253.00
AF SASH LOCK	0.00
SCREEN	22.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00
NAILING FIN	0.00
4 9/16" JAMBS	0.00
BA PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	731.00

QUOTE CONTINUED ON NEXT PAGE.

luke albers thesis project

Version 8.111 11/03/11

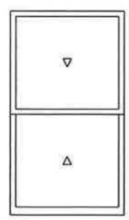
*** PRICES LISTED IN USD ***



AS VIEWED FROM THE EXTERIOR

QUOTE: 00000014	
QTY: 1 MARK UNIT -	
I TDH	632.00
WOOD - ULTREX SERIES	
CN 4276	
RO 42 1/2" X 76 1/4"	
IG - 1 LITE	
LoE-180 W/ARGON	68.00
AF SASH LOCK	0.00
SCREEN	34.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00
NAILING FIN	0.00
4 9/16" JAMBS	0.00
BA PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	734.00

22.17 Sq ft



AS VIEWED FROM THE EXTERIOR

QUOTE: 00000015	
QTY: 1 MARK UNIT -	
I TDH	632.00
WOOD - ULTREX SERIES	
CN 4276	
RO 42 1/2" X 76 1/4"	
IG - 1 LITE	
TEMP LOW E II OBSCURE W/ARG	372.00
AF SASH LOCK	0.00
SCREEN	34.00
STONE WHITE SURROUND	0.00
CHARCOAL FIBERGLASS MESH	0.00

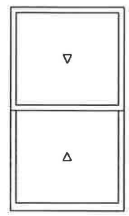
CONTINUED ON NEXT PAGE

luke albers thesis project

Version 8.111 11/03/11 PAGE 9

*** PRICES LISTED IN USD ***

NAILING FIN	0.00
4 9/16" JAMBS	0.00
BA PINE INTERIOR	0.00
STONE WHITE EXTERIOR	0.00
TOTAL PRICE	1,038.00



AS VIEWED FROM THE EXTERIOR

PROJECT TOTAL PRICE:	10,294.00

Appendix B

Luke Albers

Proposal - Detailed

Phone: Fax:

Sales Rep Name: Pella National Account Quote Dept
Sales Rep Phone:
Sales Rep E-Mail: pellaqucte@pella.com
Sales Rep Fax: (641) 621 3294

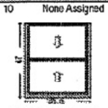
612-388-136

Customer Information	Project/Delivery Address	Order Information
LOWE'S COMPANIES INC. - 02313 00000 LOWE'S COMPANIES INC. PO BOX 1813 NORTH WILKESBORO, NC 28656 Day Phone: Mobile Phone: Fax Number: 7633674148 E-Mail: Contact Name: Great Plains #:	LOWES 2313 ATTN:JEFFREY "FAX:763-367-4148 WML RETAIL PRICING CUSTOMER:LUKE ALBERS Lot # , County: Owner Name: Owner Phone:	Quote Name: 502313032512 Order Number: 990 **Quote Number: 3591515** Order Type: Non-Installed Sales Wall Depth: Payment Terms: Tax Code: Cust Delivery Date: None Quoted Date: 3/25/2012 Contracted Date: Booked Date: Customer PO #:

2012/03/25 13:02:22 2 /4

Customer Notes: SOS# 89144 PL
SOS# 153620 AS
VENDOR# 67546

Line #	Location	Attributes	Item Price	Qty	Ext'd Price
10	None Assigned	**ProLine, Double Hung, 35.5 X 47, White, 6-9/16"**	$385.17	1	$385.17



Viewed From Exterior

PK # 509

Rough Opening: 36 - 1/4" X 47 - 3/4"
Final Wall Depth: 6-9/16"

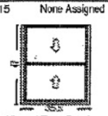
1: Non-Standard Size Double Hung, Equal Split
Frame Size: 35 1/2 X 47
General Information: Clad
Exterior Color / Finish: Standard EnduraClad, White
Interior Color / Finish: Unfinished Interior
Glass: Insulated Low E NaturalSun Argon Gas
Hardware Options: Standard Lock, Champagne, No Sash Lift
Screen: No Screen
Grille:
Wrapping Information: Foldout Fins, Factory Applied. 6-9/16" Standard 4-sided Jamb Extension, Factory Applied, Perimeter Length = 165", Glazing Pressure = 95.

For more information regarding the finishing, maintenance, service and warranty of all Pella® products, visit the Pella® website at www.pella.com

Printed on 3/25/2012 Detailed Proposal Page 1 of 3

Customer: LOWE'S COMPANIES INC. - 02313 | Project Name: LOWES 2313 ATTN:JEFFREY *FAX:763-367-4148 WML | Quote Number: 3591515

Line #	Location:	Attributes
15	None Assigned	



PK # 509

Viewed From Exterior

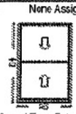
Rough Opening: 36 - 1/4" X 47 - 3/4"

Replacement: Full Screen Only. ProLine, Double Hung, 35.5 X 47

Item Price	Qty	Ext'd Price
$27.53	1	$27.53

1: Non-Standard Size Double Hung, Equal Split
Frame Size: 35 1/2 X 47
General Information: Clad
Screen Service: Full Screen Only, January 2010 - Current
Screen: Standard EnduraClad, White, InView
Wrapping Information: Perimeter Length = 165", Glazing Pressure = 95.

Line #	Location:	Attributes
20	None Assigned	



PK # 509

Viewed From Exterior

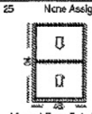
Rough Opening 48 - 3/4" X 84 - 3/4"
Final Wall Depth: 6-9/16"

Architect, Double Hung, 48 X 84, White, 6-9/16"

Item Price	Qty	Ext'd Price
$625.59	1	$625.59

1: 4884 Double Hung, Equal Split
Frame Size: 48 X 84
General Information: Standard, Style Edition, Clad, Fine
Exterior Color / Finish: Standard EnduraClad, White
Interior Color / Finish: Unfinished Interior
Glass: Insulated Low E NaturalSun Argon Gas
Hardware Options: Standard Lock, Champagne, No Sash Lift
Screen: No Screen
Grille:
Wrapping Information: Foldout Fins, Factory Applied, 6-9/16" Standard 4-sided Jamb Extension, Factory Applied, Perimeter Length = 264", Glazing Pressure = 65.

Line #	Location:	Attributes
25	None Assigned	



PK # 509

Viewed From Exterior

Rough Opening: 48 - 3/4" X 84 - 3/4"

Replacement: Full Screen Only. Architect, Double Hung, 48 X 84

Item Price	Qty	Ext'd Price
$56.34	1	$66.34

1: 4884 Double Hung, Equal Split
Frame Size: 48 X 84
General Information: Standard, Clad, Fine
Screen Service: Full Screen Only, Feb 2011 - Current
Screen: Standard EnduraClad, White, InView
Wrapping Information: Perimeter Length = 264", Glazing Pressure = 65.

Thank You For Your Interest In Pella® Products

For more information regarding the finishing, maintenance, service and warranty of all Pella® products, visit the Pella® website at www.pella.com

Printed on 3/25/2012 | Detailed Proposal | Page 2 of 3

2012/03/25 13:02:22 3 /4

Customer: LOWE'S COMPANIES INC. - 02313 | Project Name: LOWES 2313 ATTN:JEFFREY *FAX:763-367-4148 WML | Quote Number: 3591515

PELLA WARRANTY:

Pella products are covered by Pella's limited warranties in effect at the time of sale. All applicable product warranties are incorporated into and become a part of this contract. Please see the warranties for complete details, taking special note of the two important notice sections regarding installation of Pella products and proper management of moisture within the wall system. Neither Pella Corporation nor NATIONAL ACCOUNTS-INTERNAL will be bound by any other warranty unless specifically set out in this contract. However, Pella Corporation will not be liable for branch warranties which create obligations in addition to or obligations which are inconsistent with Pella written warranties.

Clear opening (egress) information does not take into consideration the addition of a Rolscreen [or any other accessory] to the product. You should consult your local building code to ensure your Pella products meet local egress requirements.

Per the manufacturer's limited warranty, unfinished mahogany exterior windows and doors must be finished upon receipt prior to installing and refinished annually, thereafter. Variations in wood grain, color, texture or natural characteristics are not covered under the limited warranty.

TERMS & CONDITIONS:

UNIT QUANTITIES AND ACCESSORIES HAVE BEEN QUOTED AS ACCURATELY AS POSSIBLE. ANY MISSED QUANTITIES OR ITEMS WILL BE SUBJECT TO AN ADDITIONAL CHARGE. PLEASE CHECK AND VERIFY WITH CUSTOMER.

PRICING IS SUBJECT TO CHANGE WITHOUT NOTICE.

ACTUAL LEAD TIME IS DETERMINED WHEN THE ORDER IS PLACED.

IF THIS QUOTE BECOMES AN ORDER, PELLA WILL NEED A SIGNATURE BY THE STORE ASSOCIATE OR THE CUSTOMER ON THIS QUOTE.

Customer Name (Please print) | Pella Sales Rep Name (Please print)

Customer Signature | Pella Sales Rep Signature

Date | Date

Note: These totals DO NOT include tax

Order Totals	
Taxable Subtotal	$1,104.63
Sales Tax @ 0%	$0.00
Non-taxable Subtotal	$0.00
Total	$1,104.63
Deposit Received	
Amount Due	**$1,104.63**

For more information regarding the finishing, maintenance, service and warranty of all Pella® products, visit the Pella® website at www.pella.com

Quote http://sstsrv.lowes.com/m2o_a/mediumQuote.jsp?projectId=10...

Back to Quote

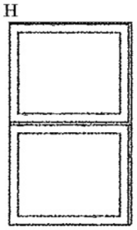
LOWE'S

LOWE'S HOME CENTERS, INC. #2313
1795 ROBERT STREET
WEST ST PAUL, MN 55118-0000
USA
(763) 367-4139

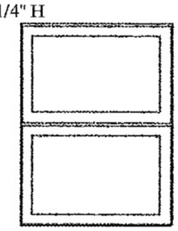
SPECIAL ORDER
Pedido especial

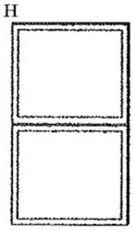
Date: 03/26/2012

Project #:	349872201	Description:	450 Dh
Customer Name:	LUKE ALBERS		
Customer Phone:	(612) 111-1111		
Customer Address:	X X, MN 55118 USA		

Line Item Frame Size	Product Code Description	Unit Price	Quantity	Total Price
0001 Frame Size = 2' 11 1/2" W x 4' 11 1/2" H RO Size = 3' 0 1/4" W x 5' 0 1/4" H 	**Manufacturer:** Pella Windows & Patio Doors Division: Millwork Product: Windows Type: Double Hungs Manufacturer: Pella Windows & Patio Doors Material: Aluminum Clad Wood Frame: Aluminum Clad Wood Frame Energy Star (R) Qualified Products Only: Yes - I would like to view only the units that are qualified for Energy Star (R). Energy Star (R) Zone: Northern Product Family: Full Frame Pella Products Product Configuration: Single Unit Room Location: OTHER 1 Opening Type: Exact Frame Size Width: 2' 11 1/2" Frame Size Height: 4' 11 1/2" Rough Opening Width: 3' 0 1/4" Rough Opening Height: 5' 0 1/4" Exterior Color: White Exterior Paint Grade: Standard EnduraClad Jambliner: Standard Jambliner Wood Type: Pine - Standard Interior Finish: Unfinished-ready for site finishing Sash Lock: Standard Sash Lifts: No Hardware Finish: Champagne Glazing: Advanced Low E Glass Tempered Glass: No High Altitude: No	$363.15	1	$363.15

Luke, I Added All windows to same quote. Price Dropped significantly on 3 x 4' window. Computers can do strange things when flipping through different options. Noticed that 4 x 7 I can only quote in 850. Let me know if you'd like me to check availability in the Pro-Line series. Jeff

	Gas Filled: Argon Sash Style: Even Grid Type: None Fiberglass Insect Screen: Full Screen Screen Color: White Screen Mesh: InView EnduraClad Exterior Trim: No Fin Type: Nail Fin Wall Depth: 6 9/16" Applied Series: 450 ProLine Will this product be installed by Lowe's?: No Lead Time: 23 Part Numbers: PTDVAUNIT PTDSCREEN (1)			
0002 Frame Size = 2' 11 1/2" W x 3' 11 1/2" H RO Size = 3' 0 1/4" W x 4' 0 1/4" H 	**Manufacturer:** Pella Windows & Patio Doors Division: Millwork Product: Windows Type: Double Hungs Manufacturer: Pella Windows & Patio Doors Material: Aluminum Clad Wood Frame: Aluminum Clad Wood Frame Energy Star (R) Qualified Products Only: Yes - I would like to view only the units that are qualified for Energy Star (R). Energy Star (R) Zone: Northern Product Family: Full Frame Pella Products Product Configuration: Single Unit Room Location: OTHER 1 Opening Type: Exact Frame Size Width: 2' 11 1/2" Frame Size Height: 3' 11 1/2" Rough Opening Width: 3' 0 1/4" Rough Opening Height: 4' 0 1/4" Exterior Color: White Exterior Paint Grade: Standard EnduraClad Jambliner: Standard Jambliner Wood Type: Pine - Standard Interior Finish: Unfinished-ready for site finishing Sash Lock: Standard Sash Lifts: No Hardware Finish: Champagne Glazing: Advanced Low E Glass Tempered Glass: No High Altitude: No Gas Filled: Argon Sash Style: Even Grid Type: None	**$315.92**	1	**$315.92**

	Fiberglass Insect Screen: Full Screen Screen Color: White Screen Mesh: InView EnduraClad Exterior Trim: No Fin Type: Nail Fin Wall Depth: 6 9/16" Applied Series: 450 ProLine Will this product be installed by Lowe's?: No Lead Time: 23 Part Numbers: PTDVAUNIT PTDSCREEN (1)			
0003 Frame Size = 4' 0" W x 7' 0" H RO Size = 4' 0 3/4" W x 7' 0 3/4" H 	**Manufacturer:** Pella Windows & Patio Doors Division: Millwork Product: Windows Type: Double Hungs Manufacturer: Pella Windows & Patio Doors Material: Aluminum Clad Wood Frame: Aluminum Clad Wood Frame Energy Star (R) Qualified Products Only: Yes - I would like to view only the units that are qualified for Energy Star (R). Energy Star (R) Zone: Northern Product Family: Full Frame Pella Products Product Configuration: Single Unit Room Location: OTHER 1 Opening Type: Exact Frame Size Width: 4' 0" Frame Size Height: 7' 0" Rough Opening Width: 4' 0 3/4" Rough Opening Height: 7' 0 3/4" Exterior Color: White Exterior Paint Grade: Standard EnduraClad Jambliner: Standard Jambliner Wood Type: Pine - Standard Interior Finish: Unfinished-ready for site finishing Sash Lock: Standard Sash Lifts: No Hardware Finish: Champagne Glazing: Advanced Low E Glass Tempered Glass: No High Altitude: No Gas Filled: Argon Sash Style: Even Grid Type: None Fiberglass Insect Screen: Full Screen Screen Color: White Screen Mesh: InView	**$673.10**	1	**$673.10**

	EnduraClad Exterior Trim: No Fin Type: Nail Fin Wall Depth: 6 9/16" Applied Series: 850 Architect Series Will this product be installed by Lowe's?: No Lead Time: 23 Part Numbers: HTDVAUNIT HTDSCREEN (1)	

Project Total: **$1,352.17**

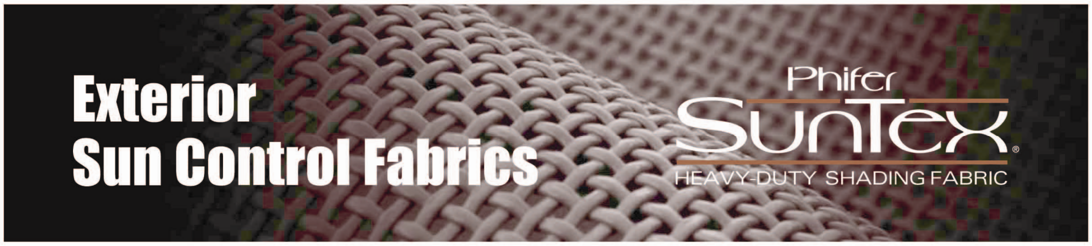
Salesperson: JEFFREY FESLER (S2313JF1)

Accepted by: ______________________ Date: 03/26/2012

Print this Page

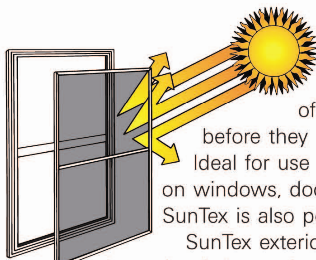
This Millwork Quote is valid until 4/ 1/2012. This is an estimate only. This estimate does not include tax or delivery charges. Delivery of all materials contained in this estimate are subject to availability from the manufacturer or supplier. All the above quantities, dimensions, specifications and accessories have been verified and accepted.

Appendix C



SunTex® Exterior Shading Fabric

Instant Relief From the Sun's Heat



SunTex is a unique woven mesh that can block 80-90% of the sun's hot rays before they enter your windows. Ideal for use as a shading fabric on windows, doors and porches, SunTex is also pet resistant.

SunTex exterior shading fabric is made of strong vinyl-coated polyester. Developed originally for use in outdoor furniture, SunTex is mildew and fade resistant and needs only an occasional cleaning with mild soap and water.

Pet Resistant • Extremely Durable
Excellent Outward Visibility
Good Ventilation

SunTex 80 - Blocks up to 80% of the sun's heat

SunTex 90 - Blocks up to 90% of the sun's heat

Ideal for Shading
Windows • Doors • Porches

SunTex 80 and SunTex 90 are available in the following colors, widths and roll lengths:
Standard Colors: Brown, Black, Grey and Stucco.
Standard Widths: 36″, 48″, 60″, 72″ and 96″ (91.4cm, 121.9cm, 152.4cm, 182.9cm and 243.8cm)
Standard Roll Length: 100 Linear Feet (30.48M)

Solar Heat Control Properties of Phifer SunTex 80 Fabrics Installed Externally, Thirty-Degree Profile Angle

	*Solar Optical Properties			Shading Coefficient w/ Single			Shading Coefficient w/ Insulating		
Color	TS	RS	AS	1/8CL	1/4CL	1/4HA	1/2CL	1CL	1HA
Brown	22	5	73	0.31	0.31	0.29	0.26	0.26	0.23
Black	24	4	72	0.33	0.33	0.28	0.28	0.27	0.24
Grey	26	24	50	0.33	0.32	0.28	0.28	0.27	0.24
Stucco	35	34	31	0.40	0.39	0.36	0.42	0.37	0.31

Solar Heat Control Properties of Phifer SunTex 80 Fabrics Installed Externally, Seventy-Five-Degree Profile Angle

	*Solar Optical Properties			Shading Coefficient w/ Single			Shading Coefficient w/ Insulating		
Color	TS	RS	AS	1/8CL	1/4CL	1/4HA	1/2CL	1CL	1HA
Brown	6	16	78	0.13	0.13	0.13	0.09	0.09	0.09
Black	7	15	78	0.14	0.14	0.14	0.09	0.09	0.09
Grey	11	51	38	0.12	0.12	0.12	0.07	0.07	0.07
Stucco	21	43	36	0.18	0.18	0.19	0.15	0.13	0.14

Solar Heat Control Properties of Phifer SunTex 90 Fabrics Installed Externally, Thirty-Degree Profile Angle

	*Solar Optical Properties			Shading Coefficient w/ Single			Shading Coefficient w/ Insulating		
Color	TS	RS	AS	1/8CL	1/4CL	1/4HA	1/2CL	1CL	1HA
Brown	11	5	84	0.21	0.21	0.20	0.17	0.16	0.15
Black	11	4	85	0.21	0.21	0.20	0.17	0.17	0.15
Grey	11	26	63	0.19	0.18	0.15	0.15	0.15	0.13
Stucco	17	46	37	0.22	0.22	0.20	0.19	0.18	0.16

Solar Heat Control Properties of Phifer SunTex 90 Fabrics Installed Externally, Seventy-Five-Degree Profile Angle

	*Solar Optical Properties			Shading Coefficient w/ Single			Shading Coefficient w/ Insulating		
Color	TS	RS	AS	1/8CL	1/4CL	1/4HA	1/2CL	1CL	1HA
Brown	2	14	84	0.11	0.11	0.11	0.08	0.08	0.08
Black	2	13	85	0.11	0.11	0.11	0.08	0.08	0.08
Grey	4	34	62	0.10	0.10	0.10	0.07	0.07	0.07
Stucco	12	62	26	0.11	0.11	0.11	0.07	0.07	0.07

* Performance evaluations conducted by Matrix, Inc., Mesa, Arizona.

TS = Solar Transmittance • RS = Solar Reflectance • AS = Solar Absorptance
1/8 CL = 1/8″ Clear Glass • 1/4 CL = 1/4″ Clear Glass • 1/4HA = 1/4″ Heat Absorbing Glass
1/2 CL = 1/2″ Clear Glass • 1 CL = 1″ Clear Glass • 1 HA = 1″ Heat Absorbing Glass

The solar optical properties are used to calculate the shading coefficient. The shading coefficient represents the percentage of solar heat gain that is transmitted to the interior through the glass and shading system. Darker colors provide maximum glare reduction and visibility.

For complete technical information, test results, performance specifications and larger samples, contact our Sun Control Marketing Department.

PHIFER WIRE PRODUCTS, INC.

Presidential "E Star" Award For Export Excellence

Founded 1952 By REESE PHIFER

P. O. BOX 1700 • TUSCALOOSA, ALABAMA 35403-1700 U.S.A.
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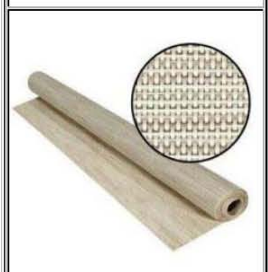
Phifer Suntex 80 & 90

Instant Relief From the Sun's Heat - SunTex is a unique woven mesh that can block 80-90% of the sun's hot rays before they enter your windows. SunTex is ideal for use as a shading fabric on windows, doors and porches. A heavy-duty shading fabric, SunTex is also pet resistant. SunTex exterior shading fabric is made of strong vinyl-coated polyester. Developed originally for use in outdoor furniture, SunTex is mildew and fade resistant and needs only an occasional cleaning with mild soap and water.

Black



Stucco

Brown

Phifer SunTex Specifications

Phifer SunTex 80	Phifer SunTex 90
Blocks up to 80% of the sun's heat.	Blocks up to 90% of the sun's heat.
Standard Colors: Brown, Black, Grey Stucco and Beige	Standard Colors: Brown, Black, Grey, Stucco and Beige
Available Widths: 36", 48", 60", 72" and 96"	Available Widths: 36", 48", 60", 72", 96" and 120"
Roll Length: 100' Standard 50' Available	Roll Length: 100' Standard 50' Available
Mesh Weight: 13.5 (oz./sqyd)	Mesh Weight: 17.2 (oz./sqyd)
Yarn Diameter: (in) .025 Warp, .025 Fill	Yarn Diameter: (in) .025 Warp, .025 Fill
Fabric Thickness: (in) .040	Fabric Thickness: (in) .039
Openness Factor: Approximately 25%	Openness Factor: Approximately 10%
Uv Blockage: Approximately 75%	Uv Blockage: Approximately 90%
Breaking Strength (lb): 400 Warp, 380 Fill	Breaking Strength (lb): 480 Warp, 340 Fill
Stiffness (Mg.): 500 Warp, 300 Fill	Stiffness (Mg.): 400 Warp, 310 Fill
Strech (%) 1.1 Warp, 3.8 Fill	Strech (%) 4.0 Warp, .1 Fill
Mesh Count: 17 x 14	Mesh Count: 23 x 16.5

Flame Retardance for Suntex:

Suntex Vinyl Coated Polyester Fabric: All meshes, all colors (Manufactured with FR Vinyl) Complies with the following standard(s).

National Fire Protection Association, NFPA No. 101, "Life Safety Code", Class"A" rating Flame Spread Index - 15 Smoke Developed Value = 350

Uniform Building Code, 1979 Edition, Part VIII, "Fire Resistive Standard for Fire Protection", Chapter 42 - Interior Wall and Ceiling Finish, Sections 4201-4205, Class I

State of California Bureau of Home Furnishing, Title 4 (Register 82, No. 42, 10/16/82), paragraph 1374, Flammability of Upolstered Furniture and Technical Bulletin 117, Section E, Fabric Applicable Commercial Standard CS-191-53.

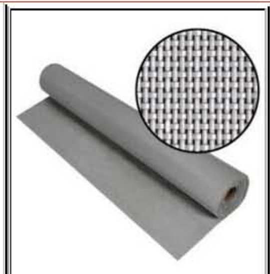
Upolstered Furniture Action Council (UFAC) Class "I" Rating

Federal Motor Vehicles Safety Standard:FMVSS 302.

Results are typical for the product and are for reference purposes only. This data cannot be used as a certification or specification.on.

We carry only Phifer Wire Products, SunTex 80 and SunTex 90. Ask for it by name. Phifer is the world leader in fiberglass, Aluminum and vinyl coated polyester screening.

We can be reached at 714 321 8109



Gray

Beige

Some 50' rolls are stock items some are "Special Order". But 50' rolls are available.

New from Phifer - Suntex 90 Design Series. 7 new colors same great product. Phifer Suntex 90 Design is available in 72" and 96" rolls only. All Suntex 90 Design rolls are 100'

Solar Screen Tax Credit Information .pdf

Microban GREENGUARD

Microban and GreenGuard Certified Products

Results are typical for the product and are for reference purposes only. This data cannot be used as a certification or specification

36" x 100' Suntex 80
Phifer SunTex instantly relieves the Sun's Heat. - Blocks the sun's hot rays before they enter your windows.
Black Stucco Brown Beige Gray

$177.98

Quantity: 1

Select Color:

Add to Cart

36" x 50' Suntex 80
Phifer SunTex instantly relieves the Sun's Heat. - Blocks the sun's hot rays before they enter your windows.
Black Stucco Brown
Beige & Gray Special Order

$97.89

Quantity: 1

Select Color:

Add to Cart

36" x 100' Suntex 90
Phifer SunTex instantly relieves the Sun's Heat. - Blocks the sun's hot rays before they enter your windows.
Black Stucco Brown Beige Gray

$211.21

Quantity: 1

Select Color:

Add to Cart

36" x 50' Suntex 90
Phifer SunTex instantly relieves the Sun's Heat. - Blocks the sun's hot rays before they enter your windows.
Black Stucco Brown
Beige & Gray Special Order

$116.16

Quantity: 1

Select Color:

Add to Cart

48" x 100' Suntex 80
Phifer SunTex instantly relieves the Sun's Heat. - Blocks the sun's hot rays before they enter your windows.
Black Stucco Brown Beige Gray

$237.30

Quantity: 1

Select Color:

Add to Cart

48" x 50' Suntex 80
Phifer SunTex instantly relieves the Sun's Heat. - Blocks the sun's hot rays before they enter your windows.
Black Stucco Brown
Beige & Gray Special Order

$130.52

Quantity: 1

Select Color:

Add to Cart

48" x 100' Suntex 90
Phifer SunTex instantly relieves the Sun's Heat. - Blocks the sun's hot rays before they enter your windows.
Black Stucco Brown Beige Gray

$281.61

Quantity: 1

Select Color:

Add to Cart

48" x 50' Suntex 90
Phifer SunTex instantly relieves the Sun's Heat. - Blocks the sun's hot rays before they enter your windows.
Black Stucco Brown
Beige & Gray Special Order

$154.89

Quantity: 1

Select Color:

Add to Cart

Phifer "BetterVue"
excellent visibility insect screening is engineered to provide a sharp view without sacrificing strength and durability in the process

"Roll-Away" Screens
Retractable screen doors that are appearing and disappearing everywhere

"Solar Screen Frame"
ideal for solar screens and large patio and deck screens

20x20 Mesh "NoSeeUm"
This fiberglass insect screen is a tightly woven mesh designed to control tiny insects

"Sliding Screen Doors "
Sliding Screen Door Kits. From 37" x 81" to 61" x97" Rollformed aluminum or Extruded.

"Screen Accessories "
Casement Clips, Pull Tabs, Window Springs and More . All you need for Screens

"Glas-Shield "
Florida_Glass: Vinyl laminated 18x14 charcoal fiberglass mesh. For use in pool enclosures to keep debris out.

60" x 100' Suntex 80 Phifer SunTex instantly relieves the Sun's Heat.- Blocks the sun's hot rays before they enter your windows. Black Stucco Brown Beige Gray $296.63 Quantity: 1 Select Color: Add to Cart	60" x 50' Suntex 80 Phifer SunTex instantly relieves the Sun's Heat.- Blocks the sun's hot rays before they enter your windows. Black Stucco Brown Beige & Gray Special Order $163.59 Quantity: 1 Select Color: Add to Cart	60" x 100' Suntex 90 Phifer SunTex instantly relieves the Sun's Heat.- Blocks the sun's hot rays before they enter your windows. Black Stucco Brown Beige Gray $352.01 Quantity: 1 Select Color: Add to Cart	60" x 50' Suntex 90 Phifer SunTex instantly relieves the Sun's Heat.- Blocks the sun's hot rays before they enter your windows. Black Stucco Brown Beige & Gray Special Order $193.61 Quantity: 1 Select Color: Add to Cart
72" x 100' Suntex 80 Phifer SunTex instantly relieves the Sun's Heat.- Blocks the sun's hot rays before they enter your windows. Black Stucco Brown Beige Gray $355.95 Quantity: 1 Select Color: Add to Cart	72" x 50' Suntex 80 Phifer SunTex instantly relieves the Sun's Heat.- Blocks the sun's hot rays before they enter your windows. Black Stucco Brown Beige & Gray Special Order $195.77 Quantity: 1 Select Color: Add to Cart	72" x 100' Suntex 90 Phifer SunTex instantly relieves the Sun's Heat.- Blocks the sun's hot rays before they enter your windows. Black Stucco Brown Beige Gray $422.42 Quantity: 1 Select Color: Add to Cart	72" x 50' Suntex 90 Phifer SunTex instantly relieves the Sun's Heat.- Blocks the sun's hot rays before they enter your windows. Black Stucco Brown Beige & Gray Special Order $232.33 Quantity: 1 Select Color: Add to Cart
96" x 100' Suntex 80 Phifer SunTex instantly relieves the Sun's Heat.- Blocks the sun's hot rays before they enter your windows. Black Stucco Brown Beige Gray $474.60 Quantity: 1 Select Color: Add to Cart	96" x 50' Suntex 80 Phifer SunTex instantly relieves the Sun's Heat.- Blocks the sun's hot rays before they enter your windows. Black Stucco Brown Beige & Gray Special Order $261.03 Quantity: 1 Select Color: Add to Cart	96" x 100' Suntex 90 Phifer SunTex instantly relieves the Sun's Heat.- Blocks the sun's hot rays before they enter your windows. Black Stucco Brown Beige Gray $563.22 Quantity: 1 Select Color: Add to Cart	96" x 50' Suntex 90 Phifer SunTex instantly relieves the Sun's Heat.- Blocks the sun's hot rays before they enter your windows. Black Stucco Brown Beige & Gray Special Order $309.77 Quantity: 1 Select Color: Add to Cart
36" x 25' Suntex 80 Phifer SunTex instantly relieves the Sun's Heat.- Blocks the sun's hot rays before they enter your windows. Stucco Only $54.48 Quantity: 1 Select Color: Add to Cart	48" x 25 Suntex 80 Phifer SunTex instantly relieves the Sun's Heat.- Blocks the sun's hot rays before they enter your windows. Black Brown Stucco $72.64 Quantity: 1 Select Color: Add to Cart	60" x 25' Suntex 80 Phifer SunTex instantly relieves the Sun's Heat.- Blocks the sun's hot rays before they enter your windows. Stucco Only $90.80 Quantity: 1 Select Color: Add to Cart	

We ship Window and Solar Screen Materials anywhere in the USA

For International shipments and shipments to Canada, please call 714 321 8109

We Ship to all 50 US States

Appendix D

Integrity from MARVIN Windows and Doors

WOOD–ULTREX DOUBLE HUNG

NFRC VALUES

THERMAL PERFORMANCE:

CERTIFIED NFRC UNIT VALUES

NFRC Glazing Type	Divider	Impact Zone	U–Factor	Solar Heat Gain Coefficient	Visible Light Transmission	Condensation Resistance	2010 Energy Star
Unit Type IDH 3.1 mm Glass Size Tested – f/s 47″ x 59″							
11/16″ IG LoE-180™ Air			0.34	0.53	0.59	51	
11/16″ IG LoE-180™ Air Obscure			0.34	0.53	0.59	54	
11/16″ IG LoE-180™ Argon			0.31	0.53	0.59	51	N
11/16″ IG LoE-180™ Argon Obscure			0.31	0.53	0.59	54	N
11/16″ IG LoE²-272® Air			0.33	0.32	0.54	52	
11/16″ IG LoE²-272® Air Obscure			0.33	0.32	0.54	52	
11/16″ IG LoE²-272® Argon			0.29	0.32	0.54	55	N NC
11/16″ IG LoE²-272® Argon Obscure			0.29	0.32	0.54	55	N NC
11/16″ IG LoE³-366® Air			0.32	0.21	0.49	53	NC SC S
11/16″ IG LoE³-366® Air Obscure			0.32	0.21	0.49	53	NC SC S
11/16″ IG LoE³-366® Argon			0.28	0.21	0.49	56	N NC SC S
11/16″ IG LoE³-366® Argon Obscure			0.28	0.21	0.49	56	N NC SC S
11/16″ IG LoE-180™ Air	GBG		0.34	0.47	0.53	51	
11/16″ IG LoE-180™ Air Obscure	GBG		0.34	0.47	0.53	54	
11/16″ IG LoE-180™ Argon	GBG		0.31	0.47	0.53	51	N
11/16″ IG LoE-180™ Argon Obscure	GBG		0.31	0.47	0.53	54	N
11/16″ IG LoE²-272® Air	GBG		0.33	0.29	0.48	52	SC
11/16″ IG LoE²-272® Air Obscure	GBG		0.33	0.29	0.48	52	SC
11/16″ IG LoE²-272® Argon	GBG		0.29	0.28	0.48	55	N NC SC
11/16″ IG LoE²-272® Argon Obscure	GBG		0.29	0.28	0.48	55	N NC SC
11/16″ IG LoE³-366® Air	GBG		0.32	0.19	0.43	53	NC SC S
11/16″ IG LoE³-366® Air Obscure	GBG		0.32	0.19	0.43	53	NC SC S
11/16″ IG LoE³-366® Argon	GBG		0.28	0.19	0.43	56	N NC SC S
11/16″ IG LoE³-366® Argon Obscure	GBG		0.28	0.19	0.43	56	N NC SC S
11/16″ IG LoE-180™ Air	SDLN < 1″		0.34	0.47	0.53	51	
11/16″ IG LoE-180™ Air Obscure	SDLN < 1″		0.34	0.47	0.53	54	
11/16″ IG LoE-180™ Argon	SDLN < 1″		0.31	0.47	0.53	51	N
11/16″ IG LoE-180™ Argon Obscure	SDLN < 1″		0.31	0.47	0.53	54	N
11/16″ IG LoE²-272® Air	SDLN < 1″		0.33	0.29	0.48	52	SC
11/16″ IG LoE²-272® Air Obscure	SDLN < 1″		0.33	0.29	0.48	52	SC
11/16″ IG LoE²-272® Argon	SDLN < 1″		0.29	0.28	0.48	55	N NC SC
11/16″ IG LoE²-272® Argon Obscure	SDLN < 1″		0.29	0.28	0.48	55	N NC SC
11/16″ IG LoE³-366® Air	SDLN < 1″		0.32	0.19	0.43	53	NC SC S
11/16″ IG LoE³-366® Air Obscure	SDLN < 1″		0.32	0.19	0.43	53	NC SC S
11/16″ IG LoE³-366® Argon	SDLN < 1″		0.28	0.19	0.43	56	N NC SC S
11/16″ IG LoE³-366® Argon Obscure	SDLN < 1″		0.28	0.19	0.43	56	N NC SC S
11/16″ IG LoE³-366® Air	SDLS < 1″		0.33	0.19	0.43	53	SC S
11/16″ IG LoE³-366® Air Obscure	SDLS < 1″		0.33	0.19	0.43	53	SC S
11/16″ IG LoE³-366® Argon	SDLS < 1″		0.29	0.19	0.43	56	N NC SC S
11/16″ IG LoE³-366® Argon Obscure	SDLS < 1″		0.29	0.19	0.43	56	N NC SC S

NOTE:
Product Values are determined using the National Fenestration Rating Council (NFRC) Procedures for determining fenestration product values.
U–Value (UV): (Btu/hr–sq ft–°F) Lower the U–Value, the greater the resistance to heat flow and better its insulating value.
R–Value (RV): (1/U–Value) Higher the R–Value, the greater the resistance to heat flow and better its insulating value.
Solar Heat Gain Coefficient (SHGC): The lower a window's SHGC, the less solar heat it transmits, and the greater its shading ability.
Visible Light Transmittance (VLT): Percentage of visible light transmitted through the unit.
Condensation Resistance (CR): Condensation Resistance measures the ability of a product to resist the formation of condensation on the interior surface of a product.
The higher the CR rating, the better that product is at resisting condensation formation.
Capillary tubes are required for IG units at high elevations. Argon will not be furnished in units with capillary tubes.

Integrity from MARVIN Windows and Doors

WOOD–ULTREX DOUBLE HUNG

NFRC VALUES

THERMAL PERFORMANCE:

CERTIFIED NFRC UNIT VALUES							
NFRC Glazing Type	Divider	Impact Zone	U–Factor	Solar Heat Gain Coefficient	Visible Light Transmission	Condensation Resistance	2010 Energy Star
Unit Type IDH Transom / Picture 3.1 mm Glass Size Tested – f/s 47″ x 59″							
11/16″ IG LoE-180™ Air			0.33	0.55	0.62	54	
11/16″ IG LoE-180™ Air Obscure			0.29	0.55	0.62	58	
11/16″ IG LoE-180™ Argon			0.33	0.55	0.62	54	N
11/16″ IG LoE-180™ Argon Obscure			0.29	0.55	0.62	58	N
11/16″ IG LoE^{2}-272® Air			0.31	0.33	0.57	56	NC
11/16″ IG LoE^{2}-272® Air Obscure			0.31	0.33	0.57	56	NC
11/16″ IG LoE^{2}-272® Argon			0.27	0.33	0.57	59	N NC
11/16″ IG LoE^{2}-272® Argon Obscure			0.27	0.33	0.57	59	N NC
11/16″ IG LoE^{3}-366® Air			0.30	0.22	0.51	56	N NC SC S
11/16″ IG LoE^{3}-366® Air Obscure			0.30	0.22	0.51	56	N NC SC S
11/16″ IG LoE^{3}-366® Argon			0.27	0.22	0.51	60	N NC SC S
11/16″ IG LoE^{3}-366® Argon Obscure			0.27	0.22	0.51	60	N NC SC S
11/16″ IG LoE-180™ Air	GBG		0.33	0.49	0.55	54	
11/16″ IG LoE-180™ Air Obscure	GBG		0.29	0.50	0.55	58	
11/16″ IG LoE-180™ Argon	GBG		0.33	0.49	0.55	54	N
11/16″ IG LoE-180™ Argon Obscure	GBG		0.29	0.50	0.55	58	N
11/16″ IG LoE^{2}-272® Air	GBG		0.31	0.30	0.51	56	NC SC
11/16″ IG LoE^{2}-272® Air Obscure	GBG		0.31	0.30	0.51	56	NC SC
11/16″ IG LoE^{2}-272® Argon	GBG		0.27	0.30	0.51	59	N NC SC
11/16″ IG LoE^{2}-272® Argon Obscure	GBG		0.27	0.30	0.51	59	N NC SC
11/16″ IG LoE^{3}-366® Air	GBG		0.30	0.20	0.45	56	SC
11/16″ IG LoE^{3}-366® Air Obscure	GBG		0.30	0.20	0.45	56	SC
11/16″ IG LoE^{3}-366® Argon	GBG		0.27	0.20	0.45	60	N NC SC
11/16″ IG LoE^{3}-366® Argon Obscure	GBG		0.27	0.20	0.45	60	N NC SC
11/16″ IG LoE-180™ Air	SDLN < 1″		0.33	0.49	0.55	54	
11/16″ IG LoE-180™ Air Obscure	SDLN < 1″		0.29	0.50	0.55	58	
11/16″ IG LoE-180™ Argon	SDLN < 1″		0.33	0.49	0.55	54	N
11/16″ IG LoE-180™ Argon Obscure	SDLN < 1″		0.29	0.50	0.55	58	N
11/16″ IG LoE^{2}-272® Air	SDLN < 1″		0.31	0.30	0.51	56	NC SC
11/16″ IG LoE^{2}-272® Air Obscure	SDLN < 1″		0.31	0.30	0.51	56	NC SC
11/16″ IG LoE^{2}-272® Argon	SDLN < 1″		0.27	0.30	0.51	59	N NC SC
11/16″ IG LoE^{2}-272® Argon Obscure	SDLN < 1″		0.27	0.30	0.51	59	N NC SC
11/16″ IG LoE^{3}-366® Air	SDLN < 1″		0.30	0.20	0.45	56	N NC SC S
11/16″ IG LoE^{3}-366® Air Obscure	SDLN < 1″		0.30	0.20	0.45	56	N NC SC S
11/16″ IG LoE^{3}-366® Argon	SDLN < 1″		0.27	0.20	0.45	60	N NC SC S
11/16″ IG LoE^{3}-366® Argon Obscure	SDLN < 1″		0.27	0.20	0.45	60	N NC SC S
11/16″ IG LoE^{3}-366® Air	SDLS < 1″		0.31	0.20	0.45	56	NC SC S
11/16″ IG LoE^{3}-366® Air Obscure	SDLS < 1″		0.31	0.20	0.45	56	NC SC S
11/16″ IG LoE^{3}-366® Argon	SDLS < 1″		0.27	0.20	0.45	60	N NC SC S
11/16″ IG LoE^{3}-366® Argon Obscure	SDLS < 1″		0.27	0.20	0.45	60	N NC SC S

Integrity from MARVIN Windows and Doors

WOOD–ULTREX DOUBLE HUNG

NFRC VALUES

THERMAL PERFORMANCE:

CERTIFIED NFRC UNIT VALUES							
NFRC Glazing Type	**Divider**	**Impact Zone**	**U-Factor**	**Solar Heat Gain Coefficient**	**Visible Light Transmission**	**Condensation Resistance**	**2010 Energy Star**
Unit Type IDH Transom / Picture 3.9 mm Glass Size Tested – f/s 47″ x 59″							
11/16″ IG LoE-180™ Air			0.34	0.53	0.62	52	
11/16″ IG LoE-180™ Air Obscure			0.34	0.53	0.62	52	
11/16″ IG LoE-180™ Argon			0.30	0.54	0.62	56	N
11/16″ IG LoE-180™ Argon Obscure			0.30	0.54	0.62	56	N
11/16″ IG LoE^2-272® Air			0.32	0.33	0.56	54	NC
11/16″ IG LoE^2-272® Air Obscure			0.32	0.33	0.56	54	NC
11/16″ IG LoE^2-272® Argon			0.28	0.33	0.56	58	N NC
11/16″ IG LoE^2-272® Argon Obscure			0.28	0.33	0.56	58	N NC
11/16″ IG LoE^3-366® Air			0.32	0.23	0.51	54	NC SC S
11/16″ IG LoE^3-366® Air Obscure			0.32	0.23	0.51	54	NC SC S
11/16″ IG LoE^3-366® Argon			0.27	0.22	0.51	58	N NC SC S
11/16″ IG LoE^3-366® Argon Obscure			0.27	0.22	0.51	58	N NC SC S
11/16″ IG LoE-180™ Air	GBG		0.35	0.35	0.48	52	
11/16″ IG LoE-180™ Air Obscure	GBG		0.35	0.35	0.48	52	
11/16″ IG LoE-180™ Argon	GBG		0.31	0.31	0.48	56	N
11/16″ IG LoE-180™ Argon Obscure	GBG		0.31	0.31	0.48	56	N
11/16″ IG LoE^2-272® Air	GBG		0.34	0.30	0.50	54	SC S
11/16″ IG LoE^2-272® Air Obscure	GBG		0.34	0.30	0.50	54	SC S
11/16″ IG LoE^2-272® Argon	GBG		0.29	0.29	0.50	58	N NC SC S
11/16″ IG LoE^2-272® Argon Obscure	GBG		0.29	0.29	0.50	58	N NC SC S
11/16″ IG LoE^3-366® Air	GBG		0.33	0.20	0.45	54	SC S
11/16″ IG LoE^3-366® Air Obscure	GBG		0.33	0.20	0.45	54	SC S
11/16″ IG LoE^3-366® Argon	GBG		0.28	0.20	0.45	58	N NC SC S
11/16″ IG LoE^3-366® Argon Obscure	GBG		0.28	0.20	0.45	58	N NC SC S
11/16″ IG LoE-180™ Air	SDLN < 1″		0.34	0.34	0.48	52	
11/16″ IG LoE-180™ Air Obscure	SDLN < 1″		0.34	0.30	0.48	52	
11/16″ IG LoE-180™ Argon	SDLN < 1″		0.30	0.34	0.48	56	N
11/16″ IG LoE-180™ Argon Obscure	SDLN < 1″		0.30	0.30	0.48	56	N
11/16″ IG LoE^2-272® Air	SDLN < 1″		0.32	0.30	0.50	54	NC SC
11/16″ IG LoE^2-272® Air Obscure	SDLN < 1″		0.32	0.30	0.50	54	NC SC
11/16″ IG LoE^2-272® Argon	SDLN < 1″		0.28	0.29	0.50	58	N NC SC
11/16″ IG LoE^2-272® Argon Obscure	SDLN < 1″		0.28	0.29	0.50	58	N NC SC
11/16″ IG LoE^3-366® Air	SDLN < 1″		0.32	0.20	0.45	54	NC SC S
11/16″ IG LoE^3-366® Air Obscure	SDLN < 1″		0.32	0.20	0.45	54	NC SC S
11/16″ IG LoE^3-366® Argon	SDLN < 1″		0.27	0.20	0.45	58	N NC SC S
11/16″ IG LoE^3-366® Argon Obscure	SDLN < 1″		0.27	0.20	0.45	58	N NC SC S
11/16″ IG LoE^3-366® Air	SDLS < 1″		0.33	0.20	0.45	54	NC SC S
11/16″ IG LoE^3-366® Air Obscure	SDLS < 1″		0.33	0.20	0.45	54	NC SC S
11/16″ IG LoE^3-366® Argon	SDLS < 1″		0.28	0.20	0.45	58	N NC SC S
11/16″ IG LoE^3-366® Argon Obscure	SDLS < 1″		0.28	0.20	0.45	58	N NC SC S
Unit Type IDH 6.9 PVB Laminate Glass Size Tested – f/s 47″ x 59″							
11/16″ IG LoE^2-272® Argon Laminate			0.36	0.22	0.48	49	S
11/16″ IG LoE^3-366® Argon Laminate	SDLN < 1″		0.36	0.19	0.42	49	S
Unit Type IDH Transom / Picture 6.9 PVB Laminate Glass Size Tested – f/s 47″ x 59″							
11/16″ IG LoE^2-272® Argon Laminate		IZ3	0.35	0.22	0.50	52	SC S
11/16″ IG LoE^3-366® Argon Laminate		IZ3	0.30	0.22	0.50	56	N NC SC S
11/16″ IG LoE^2-272® Argon Laminate	SDLN < 1″	IZ3	0.30	0.30	0.49	55	N NC SC
11/16″ IG LoE^3-366® Argon Laminate	SDLN < 1″	IZ3	0.30	0.22	0.50	56	N NC SC S
Unit Type IDH Transom / Picture 6.9 SGP Laminate Glass Size Tested – f/s 47″ x 59″							
11/16″ IG LoE^2-272® Argon Laminate		IZ3	0.36	0.23	0.50	50	S
11/16″ IG LoE^3-366® Argon Laminate		IZ3	0.31	0.22	0.50	55	NC SC S
11/16″ IG LoE^2-272® Argon Laminate	SDLN < 1″	IZ3	0.31	0.29	0.49	55	NC SC
11/16″ IG LoE^3-366® Argon Laminate	SDLN < 1″	IZ3	0.31	0.20	0.44	55	NC SC S

Appendix E

Architect Series® | Designer Series® | Pella® ProLine

HUNG

GLAZING PERFORMANCE - TOTAL UNIT

Pella® Proline Clad

Vent Units

Type of Glazing	U-Factor[1]	SHGC	VLT %	CR	U.S. Zone N	NC	SC	S	ER	Canada[2] Zone A	B	C	D
VENT UNITS													
11/16" clear IG with 2.5 mm glass	0.50	0.64	66	41									
with grilles-between-the-glass	0.50	0.57	59	41									
11/16" clear IG with 3 mm glass	0.51	0.62	65	41									
with grilles-between-the-glass	0.52	0.56	58	41									
11/16" Advanced Low-E IG with argon with 2.5mm glass	0.30	0.30	57	54					18				
with grilles-between-the-glass	0.30	0.27	50	54					16				
with Simulated Divided Light	0.30	0.27	50	54					16				
11/16" Advanced Low-E IG with argon with 3mm glass	0.30	0.30	56	54					18				
with grilles-between-the-glass	0.30	0.27	50	54					16				
with Simulated Divided Light	0.30	0.27	50	54					16				
11/16" NaturalSun Low-E IG with argon with 2.5mm glass	0.33	0.57	64	53					30				
with grilles-between-the-glass	0.33	0.51	57	53					26				
with Simulated Divided Light	0.33	0.51	57	53					26				
11/16" NaturalSun Low-E IG with argon with 3mm glass	0.32	0.56	63	52					31				
with grilles-between-the-glass	0.32	0.50	56	52					27				
with Simulated Divided Light	0.32	0.50	56	52					27				
11/16" SunDefense™ Low-E IG with argon with 2.5 mm glass	0.30	0.22	52	54					13				
with grilles-between-the-glass	0.30	0.20	47	54									
with simulated divided light	0.30	0.20	47	54									
11/16" SunDefense Low-E IG with argon with 3 mm glass	0.30	0.22	52	54					13				
with grilles-between-the-glass	0.30	0.20	46	54									
with simulated divided light	0.30	0.20	46	54									
11/16" SunDefense Dual Low-E IG with argon with 2.5 mm glass	0.26	0.21	48	44					18				
with grilles-between-the-glass	0.26	0.19	43	44					17				
with simulated divided light	0.26	0.19	43	44					17				
11/16" SunDefense Dual Low-E IG with argon with 3 mm glass	0.26	0.21	47	44					18				
with grilles-between-the-glass	0.26	0.19	42	44					17				
with simulated divided light	0.26	0.19	42	44					17				

Shaded Areas Meet ENERGY STAR® Performance Criteria in Zones Shown

R-Value = 1/U-Factor
SHGC = Solar Heat Gain Coefficient
VLT % = Visible Light Transmission
CR = Condensation Resistance
ER = Canadian Energy Rating

See the Product Performance section for more detailed information or visit www.energystar.gov for Energy Star guidelines.

(1) Glazing performance values are calculated based on NFRC 100.
(2) The values shown are based on Canada's updated ENERGY STAR® initiative.

For center-glass values, see the Product Performance section.

See Casement Section for Fixed unit Glazing Performance.

Climate Zones